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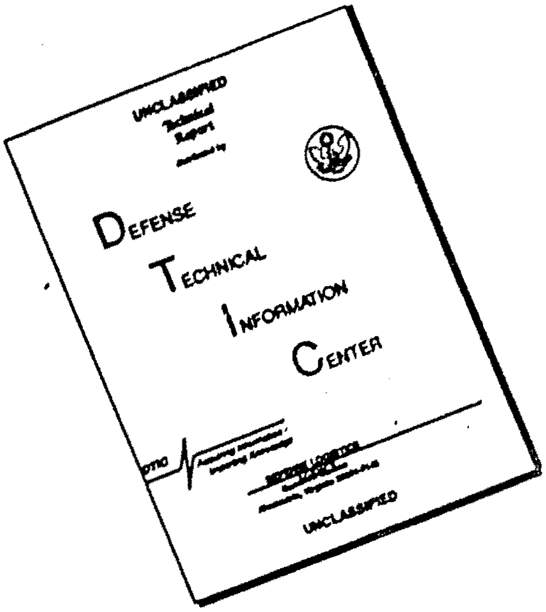

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ARTILLERY DIVISION

REPORT ON

FUNCTIONING AND SPALL CHARACTERISTICS OF 90-MM, T142E3, HEP SHELL, COMP A3-LOADED AND FUZED WITH A BD, M91A1 FUZE (U)

Fourth Report On Ordnance Project TW-426

(D/A Project No. 504-01-001)

L. R. NEALLEY

JULY 1959

Aberdeen Proving Ground
Maryland

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FUNCTIONING AND SPALL CHARACTERISTICS OF 90-MM, T142E3, HEP SHELL, COMP A3-LOADED AND FUZED WITH A BD, M91A1 FUZE (U)

Fourth Report on Ordnance Project No. TW-426

Dates of Test: 23 October to 25 November 195[illegible]

ABSTRACT (C)

The purpose of ~~conducting~~ this test was to determine the functioning and spall characteristics of Shell, 90-mm, HEP, T142E3, Comp A3-loaded and fuzed with Fuze, BD, M91A1. The results include: impact photos, fuze functioning times, facial and spall area dimensions, spall velocity, spall weight, and spall kinetic energy for rounds fired at velocity levels of 1000, 1700, and 2600 fps against four-inch armor plate, set at both 0° and 60° obliquity. The conclusions are: (1) The T142E3, HEP shell, comp A3-loaded and fuzed with a BD, M91A1 fuze is ineffective at velocity levels of 2600 fps against 0° plate and 1000 fps against 60° plate; (2) The T142E3, HEP shell, comp A3-loaded and fuzed with a BD, M91A1 fuze is most effective when fired at a velocity level of 1700 fps against 0° plate. It is recommended that development of the T142E3, HEP shell be continued in order to make it effective when fired at velocity levels of 2600 fps or above against 0° plate.

CONTENTS

1. (C) INTRODUCTION

This test is one of a series which is being fired to gain information on the performance and characteristics of rotated HEP ammunition. The 90-mm, T142E3, HEP shell has been selected as the test vehicle for this series of tests. Prior tests in this series have provided information on the metal parts configuration of the shell at various degrees of "crush-up" against armor plate, and the deceleration characteristics of the shell as it crushes up against armor plate. This test is being fired for two reasons: first, to investigate the functioning and spalling characteristics of the standard 90-mm, T142E3, HEP shell, loaded with composition A3 and fuzed with a BD, M91A1 fuze; second, the results of this test will provide a basis against which the results of future firings of new designs of 90-mm, HEP shell can be compared. Two other tests in this series are being planned. They will deal with new methods of determining the metal parts configuration of the shell at various degrees of crush-up.

This report contains the results of fuze functioning time, spall size, weight, velocity, and kinetic energy, and size of facial impressions. Also contained in this report is some information about the impact characteristics of the shell. The rounds were fired at velocity levels of 1000, 1700, and 2600 fps with the plate set at both 0^{o} and 60^{o} obliquity.

2. (U) DESCRIPTION OF MATERIEL

The shell used for this test were the standard 90-mm, T142E3, HEP shell, loaded with composition A3. Most of the shell were fuzed with live, standard, BD, M91A1 fuzes. However, to gain some insight into the problem of nose initiation a few of the shell were fuzed with inert BD, M91A1 fuzes.

3. DETAILS OF TEST

3.1 Method of Testing

(C) This test covered the functioning and spall characteristics of the subject shell when fired at 4-inch armor plate at velocity levels of 1000, 1700, and 2600 fps with the plate set at both 0^{o} and 60^{o} obliquity. Two inert-fuzed, live-loaded rounds were fired at each of the above conditions of velocity and plate obliquity. This was done in order to determine under what conditions the round could be functioned without a fuze.

(C) Three cameras were used to obtain the desired information. One camera recorded the impact and detonation, another the fuze functioning time, and the third recorded the flight of the spall. The gun was fired through a T3 firing box which started the cameras running but delayed the firing of the gun so that the cameras would be operating at full speed when the round reached the plate.

(C) The fuze functioning time setup was as follows. A make circuit screen was set approximately one-half inch from the face of armor plate. Connected to this screen were two M36 detonators. The instant that the nose of the shell pushed the screen into contact with the armor plate a circuit was completed and the detonators were fired. This flash was recorded by the camera. The round then crushed-up and was detonated and the detonation flash was also recorded by the camera. The camera contained a timing light which was continuously putting timing marks on the film every tenth of a millisecond. The functioning time was then determined by measuring the distance between flashes (detonators and detonation of the round) and converting this into time by using the timing marks as a base (see Figure 8). Two correction factors were then applied. They were the inherent time delay of the detonators and the physical distance between the point of detonation of the detonators and the point of detonation of the round.

(C) A second method was also used to determine fuze functioning time. This method utilized a photomultiplier tube and a single-sweep oscilloscope. The primary winding of an air-core transformer was inserted into the detonator circuit. The completion of the circuit (when the wire screen came in contact with the plate) allowed a current to flow in the primary winding of the transformer. This current induced sufficient voltage into the secondary winding to trigger the oscilloscope. Once the sweep of the scope trace had been triggered, the photomultiplier tube which was used as the sensing device had complete control over the rise and fall of the signal trace. The photomultiplier tube "sensed" the intensity of light it viewed and this "sensing" was converted into a voltage signal which was relayed to the oscilloscope. The voltage signal relayed was inversely proportional to the intensity of the light (i.e., an increase in intensity of light decreased the voltage, which in turn caused the trace to rise). The detonator flash was traced as a descending line due to the fact that the flash reached its highest intensity almost immediately upon initiation and from that point on it gradually decreased. Whenever the detonation of the round occurred, the sudden increase in the intensity of light caused the trace to rise sharply. A Polaroid camera was attached to the oscilloscope and the shutter was left open so that the film would record the sweep of the scope trace. After the sweep of the scope trace had been recorded the camera position was changed slightly and fifty microsecond calibration lines were put on the scope and a picture of these was taken. The camera was repositioned again and ten microsecond calibration lines were put on the scope and a picture of these was taken. Therefore each Polaroid shot contained a picture of the sweep of the trace during functioning and calibration lines ten and fifty microseconds apart (see Figures 16 and 17).

(U) Both the 16-mm smear camera and the photomultiplier tube were positioned so as to view the area from 3 to 6 inches from the plate. This was done so that the plate flash (if present) would not be confused with the functioning flash.

(U) The method which utilized an oscilloscope and photomultiplier tube is still somewhat in the experimental stage. One may note on the tabulation of results that in quite a few cases the functioning times were lost. This is due to the fact that minor changes were being continuously made on the equipment

during the test. In some cases these changes were detrimental and the results were lost. Anyone considering the results of fuze functioning times should consider the camera results to be more accurate than the electronic results. In any place in this report where times are mentioned they will be camera times unless they are specified as electronic times.

(C) An 8-mm framing camera with a rate of 10,000 frames per second was used to observe the impact and detonation of each round. The information recorded by this camera was used to determine any pertinent information about the flight of the round prior to impact and to observe any indication of nose functioning on impact.

(C) As a means to determine spall velocity, a 16-mm framing camera, with a rate of 4000 frames per second, was used to record the flight of the spall. The camera was positioned so as to view a portion of the line of flight of the spall but not the section of the plate where the spall was initiated. In order to obtain a reference on the film as to when the spall was initiated the following system was used. A break circuit trigger was taped on the rear of the plate over the section where it was anticipated that the spall would be initiated. The trigger consisted of a piece of paper with a grid of silver, conductive paint on it. Two leads connected the trigger circuit into the circuit of the timing light for the camera. While the camera was running but prior to the initiation of any spall, the trigger circuit shorted the timing light out so that no timing marks appeared on the film. When the plate bulged out as the spall was initiated, the trigger was broken and the timing light began to put timing marks on the film at 1-millisecond intervals. The spall came off the plate and eventually into the field of view of the camera. Also located in the field of view of the camera was a reference background. During the 0° plate firing the reference was a flat block of concrete and during the 60° firing the reference was a small pile of celotex. Depending upon the obliquity of the plate, the spall would hit the concrete or pass through the celotex pile into the ground. After each round the distance that the spall traveled from the spalled area to the spot where it hit on the reference background was measured. Thus from the combination of pictures of the spall impacting on the reference background, timing marks from the time the spall is initiated, and the distance from spall area to the point of impact on the reference background, the spall velocity can be accurately determined (see Appendix C-4 to C-9. Timing marks were cut off when film was trimmed).

(C) The references mentioned in the previous paragraph (concrete and celotex) were also very useful in the recovery of the spall. During the 0° obliquity firing the spall rebounded from the concrete and could be found in the immediate area. During the 60° obliquity firing the celotex slowed the spall down and it also could be found in the immediate area.

3.2 (C) Results

The results of this test are tabulated as follows:

Table I. Summary of Results

Tube Rd No.	Striking Velocity, fps	Facial Impression, in. Hor	Vert	Depth	Spall Area, in. Hor	Vert	Depth	Major Spall[a] Number of Pieces	Weight of Recovered, lb	Average Velocity, fps	Kinetic Energy, ft-lb	Functioning Time, microseconds Camera	Electronic	Remarks
								Plate at 0° Obliquity						
5	Assumed 2590	See Remarks and Observations, first paragraph.						-	-	-	-	53	Lost	Nose initiated.
6	Assumed 2587	See Remarks and Observations, first paragraph.						-	-	-	-	54	100	Nose initiated.
7	2530	See Remarks and Observations, first paragraph.						-	-	-	-	54	Lost	Inert fuzed; nose initiated.
8	2597	See Remarks and Observations, first paragraph.						-	-	-	-	53	60	Inert fuzed; nose initiated.
9	1721	8	Diameter	3/8	8	8-1/4	1	1 Recovered 1 Missing	1.88	561	-	408	412	
10	1662	8	Diameter	3/8	8-1/2	7-3/4	1	2	7.54	595	41,200	402	419	
11	1647	8	Diameter	3/8	8	8-1/2	1	3	7.57	655	50,400	307	Lost	
45	1609	8	Diameter	3/8	7-3/4	9	1-1/2	2	7.62	563	36,300	348	257	
46	1636	7-1/2	Diameter	1/2	8-1/4	7-3/4	7/8	2	7.20	604	40,800	361	364	
47	1623	See Remarks and Observations, second paragraph.						-	-	-	-	752	Off Scale	Inert fuzed.
48	1634	See Remarks and Observations, second paragraph.						Some burning; did not function high order.				-	-	Inert fuzed.
49	Assumed 2572	See Remarks and Observations, first paragraph.						-	-	-	-	49	56	
50	Assumed 2582	See Remarks and Observations, first paragraph.						-	-	-	-	Lost	54	Nose initiated.
51	Assumed 2560	See Remarks and Observations, first paragraph.						-	-	-	-	Lost	52	Nose initiated.
52	1001	6-1/2	Diameter	1/2	6-1/2	7	7/8	1	5.58	Lost	-	Lost	336	Nose initiated.
53	979	6-3/4	Diameter	1/2	6-3/4	7	7/8	2	6.56	476	23,000	308	342	
54	984	7	Diameter	1/2	6	6-3/4	7/8	1	3.84	567	19,200	307	351	
55	988	6-1/2	Diameter	1/2	6-3/4	6	3/4	2	5.44	470	16,100	298	339	
56	965	6	Diameter	1/2	6-1/2	5	3/4	2 Recovered 1 Missing	1.85	738 514 416	-	298	340	
57	991	Very small amount of burning; explosive scattered around butt.							-	-	-	-	-	Inert fuzed.
58	991	Very small amount of burning; explosive scattered around butt.							-	-	-	-	-	Inert fuzed.
59	988	6	Diameter	1/2	5-3/4	4	1	1 Not Recovered	-	406	-	276	285	
60	2566	See Remarks and Observations, first paragraph.						-	-	-	-	47	65	

Tube Rd No.	Striking Velocity, fps	Facial Impression, in. Hor	Facial Impression, in. Vert	Facial Impression, in. Depth	Spall Area, in. Hor	Spall Area, in. Vert	Spall Area, in. Depth	Major Spall[a] Number of Pieces	Major Spall[a] Weight of Recovered, lb	Major Spall[a] Average Velocity, fps	Major Spall[a] Kinetic Energy, ft-lb	Functioning Time, microseconds Camera	Functioning Time, microseconds Electronic	Remarks
								Plate at 60° Obliquity						
61	Assumed 1638	7-3/4	9-3/4	1/2	5	7-3/4	1-3/8	1	8.12	379	18,100	324	363	
62	1658	7-1/2	10	1/2	6	7-3/4	1-1/4	1	7.24	389	17,000	311	347	
63	1650	7	9-1/4	3/8	6-1/2	7-1/2	1-1/4	1	7.82	271	8,900	294	330	
64	1607	7	9-1/2	3/8	6	7-1/2	1-1/8	1	7.30	419	19,900	287	322	
65	1659	7-1/2	9-1/2	3/8	5-1/2	6-3/4	1-1/4	1	6.08	432	17,600	273	Lost	
66	1[illegible]	No detonation or burning; small amount of plate flash							-	-	-	-	-	Inert fuzed.
67	1[illegible]88	No detonation or burning; small amount of plate flash.							-	-	-	-	-	Inert fuzed.
68	257[illegible]	6-1/2	7-1/2	3/8	5	5	Hinged Out 1-1/2	Slight overlap on tube round 65.				277	Lost	Hinged from 11 to 2 o'clock.
69	2589	See Remarks and Observations, third paragraph.						-	-	-	-	49	65	Nose initiated.
70	258[illegible]	[illegible]	9-1/2	3/8	5-1/4	7	7/8	1	7.62	Lost	-	259	292	
71	2[illegible]	8	10-1/2	3/8	6	6-1/2	1	1	8.66	359	15,200	242	272	
72	2589	No facial impression. Large ball of fire observed visually.								-	-	1098	Lost	Inert fuzed.
73	2584	No facial impression. Large ball of fire observed visually.								-	-	-	-	Did not function high order. Inert fuzed.
74	Assumed 990	[illegible]	8-1/2	3/8	4-1/2	6	Bulged Out 7/8	-	-	-		338	Lost	Bulge cracked from 4 to 11 o'clock.
75	981	5-3/4	6-1/4	3/8	4-1/2	6	Bulged Out 3/4	-	-	-	-	388	Lost	Bulge cracked from 7 to 10 o'clock.
76	973	6	6-1/2	3/8	4-3/4	6	Bulged Out 7/8	-	-	-	-	403	Lost	Bulge cracked from 4 to 9 o'clock.
77	977	6	6-1/2	3/8	5	6-1/2	Bulged Out 3/4	-	-	-	-	355	418	Bulge cracked from 5 to 8 o'clock.
78	906	5-3/4	6-1/4	3/8	4-3/4	6	Bulged Out 3/4	-	-	-	-	348	384	Bulge cracked from 4 to 9 o'clock.
79	982	No detonation or burning.						-	-	-	-	-	-	Inert fuzed.
80	973	6-3/4	9-3/4	1/4	No indication of bulge on rear of plate.					-	-	738	Lost	Inert fuzed.
81	2550	7	[illegible]-1/2	1/4	6-1/2	7-1/2	1	1	-	-	-	266	287	Round impacted above a 12 by 12 inch brace. Spall started to leave plate but was held back by the brace (see Appendix C-3).
82	2574	6	10	1/4	6-3/4	8-3/4	1	1	8.94	371	19,100	266	-	
83	2568	7-3/4	10	1/4	6-1/2	8-1/2	1	2	9.10	312	13,800	258	260	
84	2582	8	10	1/4	5-1/2	7-1/4	3/4	1	7.64	256	7,800	257	264	

[a]Recovered spall identified as part of original face of the plate (rear). No secondary spall was recovered.

3.3 Remarks and Observations

(C) The facial impressions of all rounds impacting at the 2600 fps velocity level with the plate set at 0° obliquity were all the same as for tube rounds 6 and 7 which are shown in Figures 1, 2, 3, and 4. Tube round 6 contained a live fuze and round 7 was inert-fuzed. The diameter of the small circle in the center was from 3 to 3-3/4 inches. In most cases it was dished out to a depth of 1/4 inch. The surfaces of the small circles were fairly smooth except for tube round 7 in which case the edges were somewhat built up by a deposit of metal. From the edge of the small circles to a diameter of 7-1/4 to 8 inches the area was heavily "washed" and was very rough and uneven. The whole area of approximately eight inches in diameter was yellowish. At a radius of approximately sixteen to seventeen inches from the center of the small circle there was a ring of fragmentation marks. This ring of fragmentation marks consisted of two distinctly different types of marks. One type was caused by the impact of copper fragments from the rotating band. These marks were copperish in color and had little or no depth. The other marks were caused by steel fragments and were gouged out to a depth of 1/8 to 1/4 inch. One other noticeable feature of the ring of marks was the even distribution of the two types in an almost alternating pattern. First there would be a copper mark, then a steel mark, then perhaps two copper marks, a steel mark, a copper mark, etc. The copper marks ranged from 1 to 2 inches in length while the steel marks were two to three times as long. Since the facial impressions and functioning times of the inert-fuzed rounds and live-fuzed rounds are the same it can be seen that the fuze has no effect on the functioning of the round. The rounds are functioned high order due to the high velocity of impact on the plate. It should be noted here that the type of functioning (high order or low order) was determined by viewing the photographs of impact and detonation of the round. A function was considered high order if the frame (or frames) in which the function occurred was completely blanked out by the functioning flash (see Figure 11, last frame). If the frame (or frames) in which functioning occurred was not completely blanked out (i.e., some of the background or plate could be seen) the function was considered low order (see Figure 11, frames 4 through 7).

(C) The facial impressions of tube rounds 47 and 48, which were inert-fuzed, consisted of small circles approximately three inches in diameter. They were yellowish in color and had no depth. Round 47 functioned high order after an initial period of burning. Round 48 had the same type of initial burning but did not function high order.

(C) The facial impression for round 69 is shown in Figure 5. This was the only round of ten fired under the same conditions (2600 fps; 60° obliquity plate), including two inert-fuzed rounds, which functioned in this manner. The facial impression is analogous to the facial impressions of rounds fired at the 2600-fps velocity level at 0° plate. The facial impression and the short functioning time indicate that this round was functioned from the nose on impact. The center impression measured 4-1/2 inches vertically and 3 inches horizontally. It was smooth and slightly dished out. The rest of the area, triangular in shape, was deeply gouged and washed, especially where the base impacted.

Figure 1: Tube Round 6; Striking Velocity 2587 fps. 0° Plate. Standoff View.

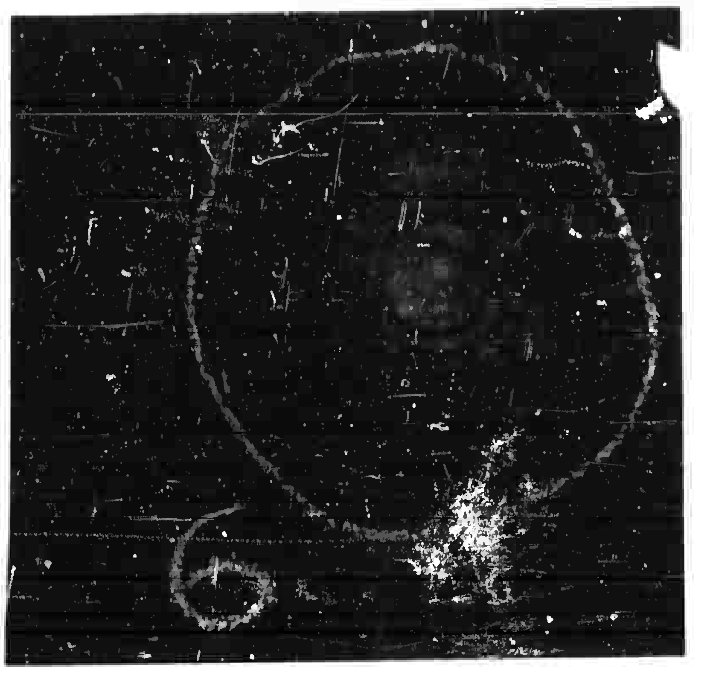

Figure 2: Tube Round 6; Striking Velocity 2587 fps. 0° Plate. Closeup View.

Figure 3: Tube Round 7; Striking Velocity 2530 fps. 0° Plate. Standoff View.

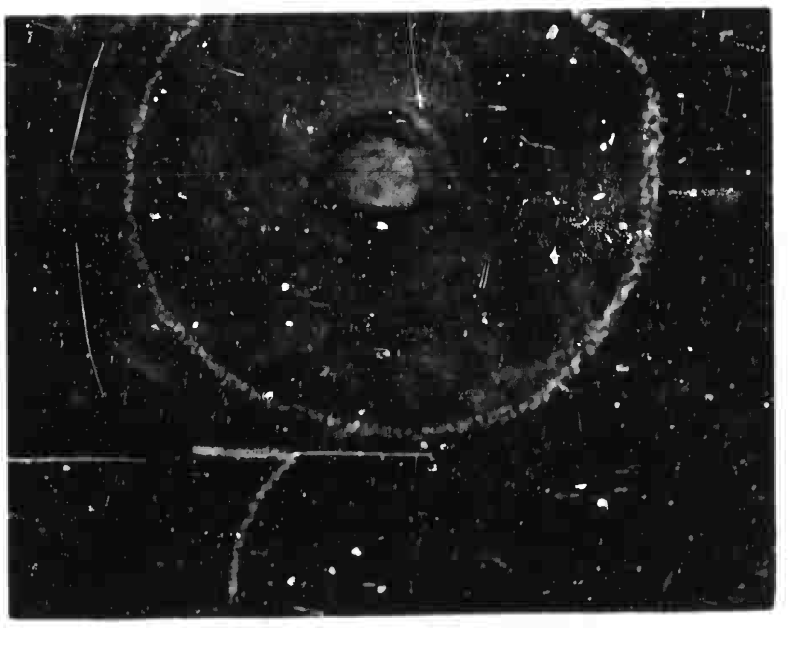

Figure 4: Tube Round 7; Striking Velocity 2530 fps. 0° Plate. Closeup View.

Figure 5: Facial Impression for Round 69.

(C) After a complete study of the impact photographs and film of the functioning times it was seen that in many cases the rounds were starting to function low order from the nose prior to detonation from the base. Definite high-order functioning initiating from the nose was observed in some cases. Figure 6 illustrates the low-order type of nose functioning. The first three frames in Figure 6 show the round prior to impact. The fourth frame shows the round after it has impacted and started to crush up. The flash at the base of the plate is the detonators which have functioned during the time between the third and fourth frames. The arrow indicates the flash caused by the round starting to function from the nose. The following frame shows the round starting to function from the base. The indication of base functioning may not be readily discernible due to the difficulty in reproducing a photograph of this type. The original negative and glossy prints show fire breaking out from around the rotating band and around the baseplate and fuze. The nose functioning has grown so large that the round is almost entirely obscured. In the last frame shown the round has functioned high order.

(C) The question may arise as to whether this flash which appears to be nose functioning is actually plate flash. Figure 7 shows a completely inert round impacting on a 60° plate at a velocity of 2549 fps. The photographs were taken against a very dark background so that any flash is readily apparent. The round is not visible due to the dark background. In the first frame the round has not impacted. In the second frame the detonator flash (arrows point to detonator flashes in all frames) indicates that the round has impacted on the plate. The first indication of plate flash appears in the fourth frame (plate flash is circled in frames 4 through 7).

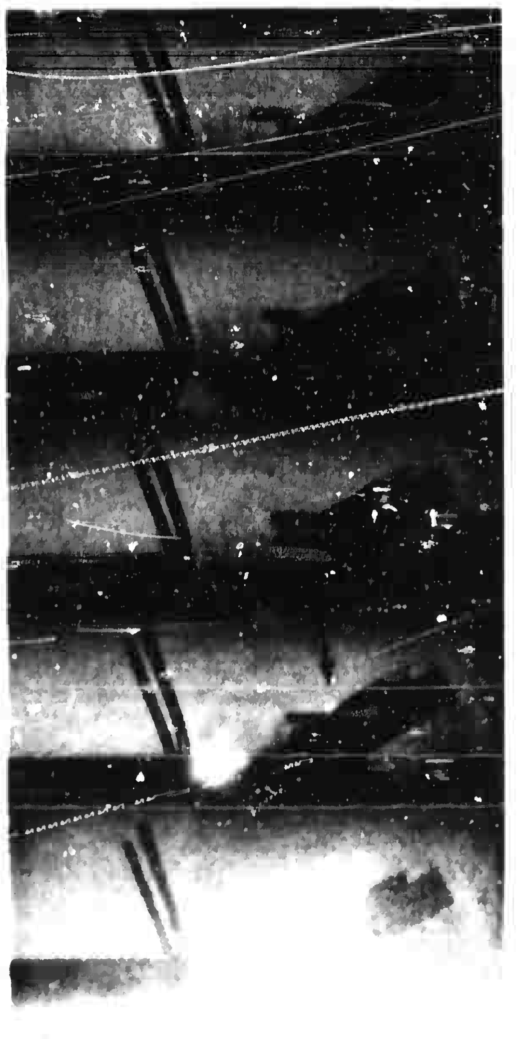

Figure 6: Tube Round 82; Striking Velocity 2574 fps.

In Figure 6 the flash at the nose appears in the same frame as the detonator flash, whereas in Figure 7 the plate flash does not appear until the second frame after the detonator flash and is very small. In Figure 7 the camera was focused on some of the face of the plate whereas in Figure 6 the camera was focused directly across the face of the plate. A comparison of Figures 6 and 7 shows that the flashes do not occur at the same time and that the plate flash is not as large as the nose functioning flash.

(C) Figure 8 is a print of the smear film from which the fuze-functioning time of tube round 82 was computed. Point 1 is the detonator flash, point 2 is the beginning of functioning, and point 3 is the main function. The dots running along the top of the print are timing marks which are 1/10 millisecond apart. If zero time is established where the flash of the detonator starts (indicating that the nose of the round has touched the plate), the time until the initial function or nose function occurs is 83 microseconds. The time from impact until the main function occurs is 266 microseconds (correction factors applied on all readings). This means that for a period of 183 microseconds some of the explosive on the face of the plate is being consumed.

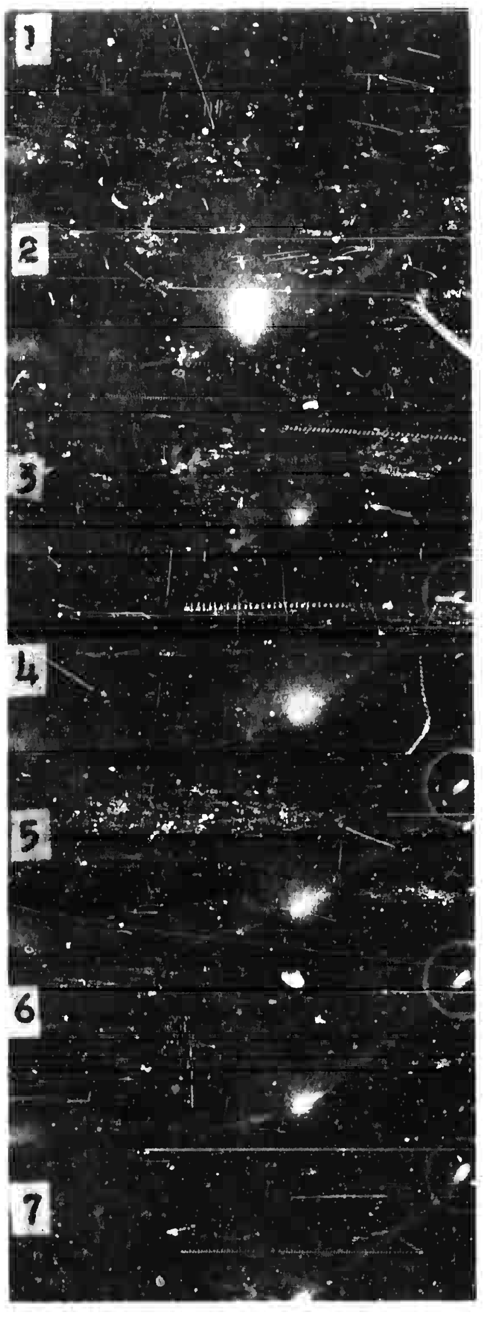

Figure 7: Striking Velocity 2549 fps. Photograph Taken During Another Test of 90-mm, T142E3, HEP Shell (Reference 3).

(C) Figure 9 is the smear film for the inert round (shown in Figure 7) which impacted on the 60° plate. The detonator flash is shown at point 1 and the start of the plate flash is shown at point 2. The time from impact until the plate flash is recorded is 181 microseconds. This time is 53 microseconds longer than the average time of nose functioning for seven live-loaded rounds fired under the same conditions (see Table II). One other fact that should be noted is that of six inert rounds fired at velocities of 1700, 2600, and 3000 fps at 0° and 60° plate, the round shown in Figures 7 and 9 was the only one for which any plate flash was recorded on the smear camera. On all the other rounds the plate flash was not large enough to be recorded.

(C) The nose function appears to be low order and is probably caused by small pieces of explosive which are compressed between parts of the shell wall and the face of the plate, as indicated in Figure 10. The nose functioning may be very small to start with but it can advance to a high-order detonation, as is evidenced by Figure 11, which shows the impact of tube round 47 which was inert-fuzed. The initial function started 204 microseconds after impact and the high-order function occurred at 752 microseconds after impact (see Appendix C-1).

Figure 8: Smear Film for Tube Round 82.

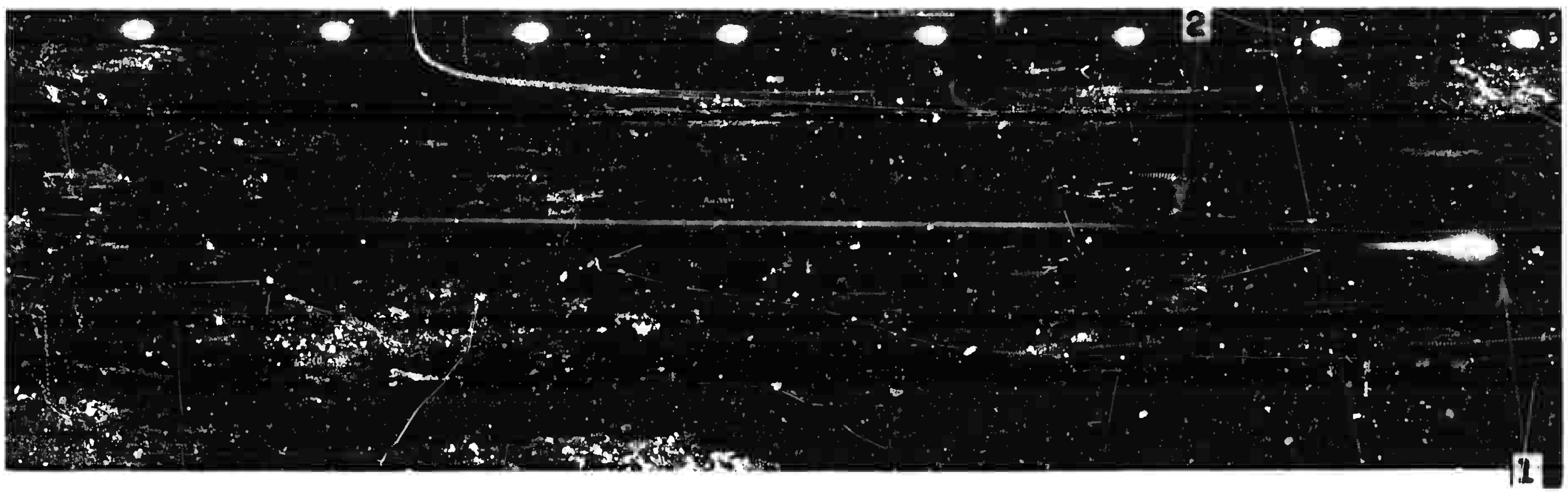

Figure 9: Smear Film of Inert Round; 60° Plate Obliquity, Striking Velocity 2544 fps (Reference 3).

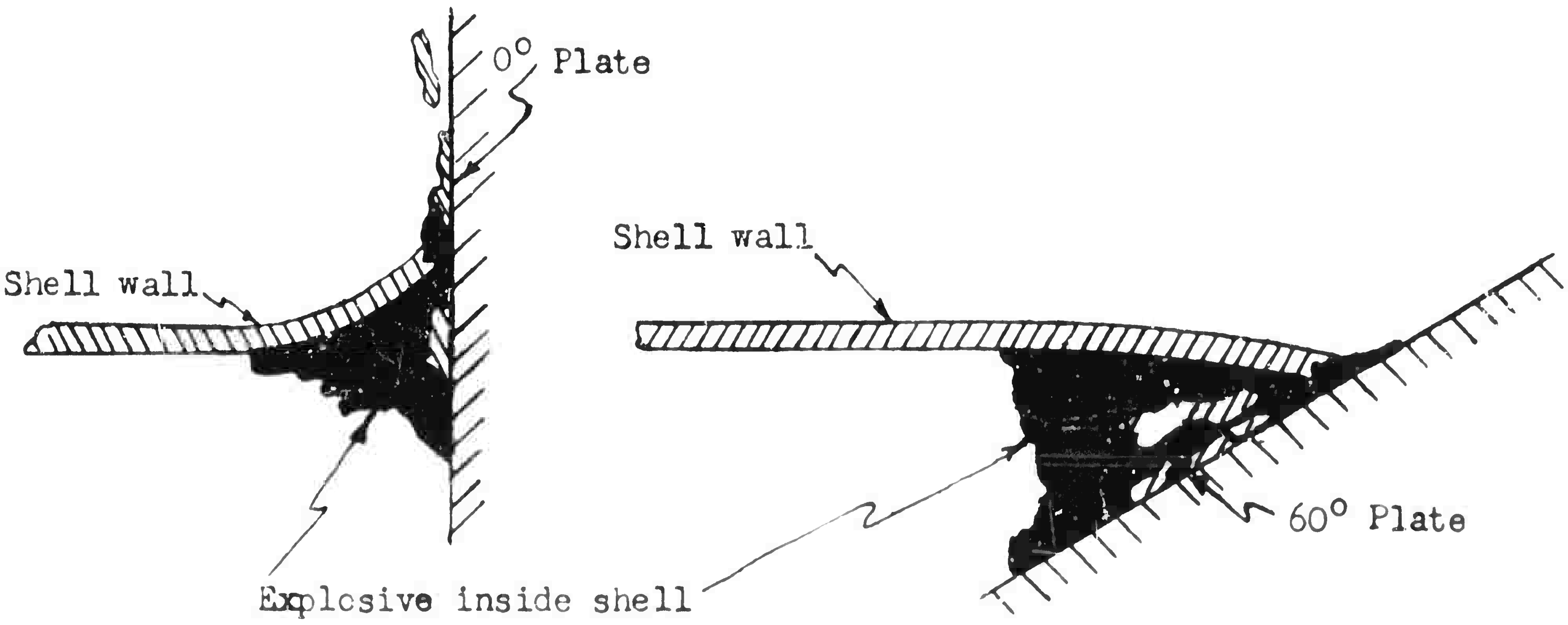

Figure 10.

(C) Tube round 48 also contained an inert fuze and was fired under the same conditions as tube round 47. This round did not function high order. The initial function in this case started at 194 microseconds after impact and the complete function was a burning type of function.

(C) Further evidence that the nose functioning is not plate flash is seen in Figure 12 which shows a completely inert shell impacting the plate at 1681 fps. The plate is slightly bowed due to previous impacts but there is no evidence of any plate flash.

Figure 11: Tube Round 47; Striking Velocity 1623 fps. Inert-Fuzed.

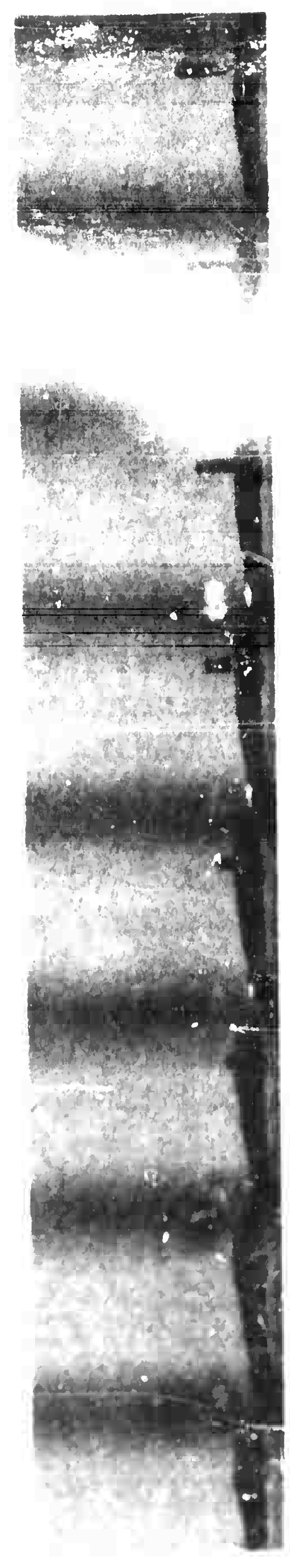

Figure 12: Inert Round; Striking Velocity 1681 fps.

(C) Figures 13 and 14 show a typical base function that occurs without any initial nose function. The fifth frame in Figure 13 shows the round with fire breaking out from around the rotating band. There is no indication of any flash around the nose. This is also shown on the fuze-functioning time film (Figure 15) which indicates that the function starts from a very small point and quickly spreads out.

Figure 13: Tube Round 54; Striking Velocity 984 fps.

(C) Definite high-order nose initiation was observed for all rounds which were fired at a velocity level of 2600 fps with the plate set at 0°. Figures 12 and 13 show typical impact and functioning time photographs for one of these rounds. In one case, a round was nose initiated when fired at 60° plate at the 2600 fps velocity level. Also in one case, an inert-fuzed round (tube round 80) was nose-initiated when fired at 60° plate at the 1000 fps velocity level. The nose initiation of an inert-fuzed round fired at 60° plate at a velocity level of 1000 fps is a very uncommon occurrence. The functioning time of 738 microseconds indicates that the round was crushed up 7 to 8 inches when the functioning occurred. One possible explanation for this detonation is as follows. During a previous test an inert round, which was fired at a striking velocity of 1000 fps at 60° plate, was recovered (see photograph in Appendix C-10). Various other rounds fired under the same conditions were also lying in the general area. The recovered round and X-rays of the rounds crushing up all indicate that at this velocity and plate obliquity the round splits open along the bottom and is somewhat deformed. In the particular detonation

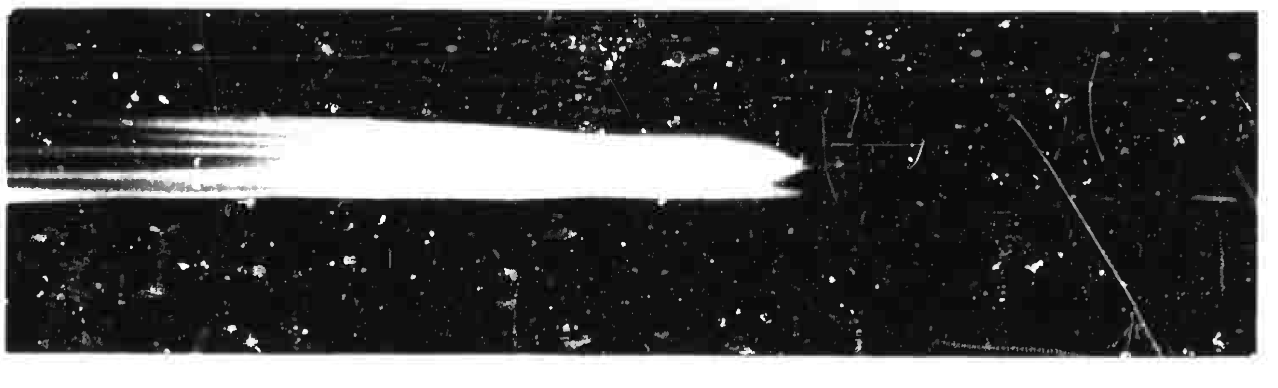

Figure 14: Functioning Time Film; Tube Round 54.

that occurred during this test, the round probably crushed in the same manner as the recovered round. However, since the round remains fairly well intact during crush-up the explosive is compressed to a great degree. Since the explosive is press-loaded to 8000 psi during initial loading of the shell the additional amount of compression during crush-up may be enough to cause the explosive to detonate. Tube round 79 was fired under the same conditions as tube round 80. This round did not detonate and it may be due to the fact that the round might have broken up more than tube round 80, thus relieving some of the pressure on the explosive.

(C) The inert-fuzed rounds fired at the 1700 fps level at 60° plate did not detonate. This is probably due to the fact that they are broken up a great deal more than the lower velocity rounds.

(C) Table II summarizes the functioning times for all the rounds that either indicated some type of nose functioning or were nose-initiated high order.

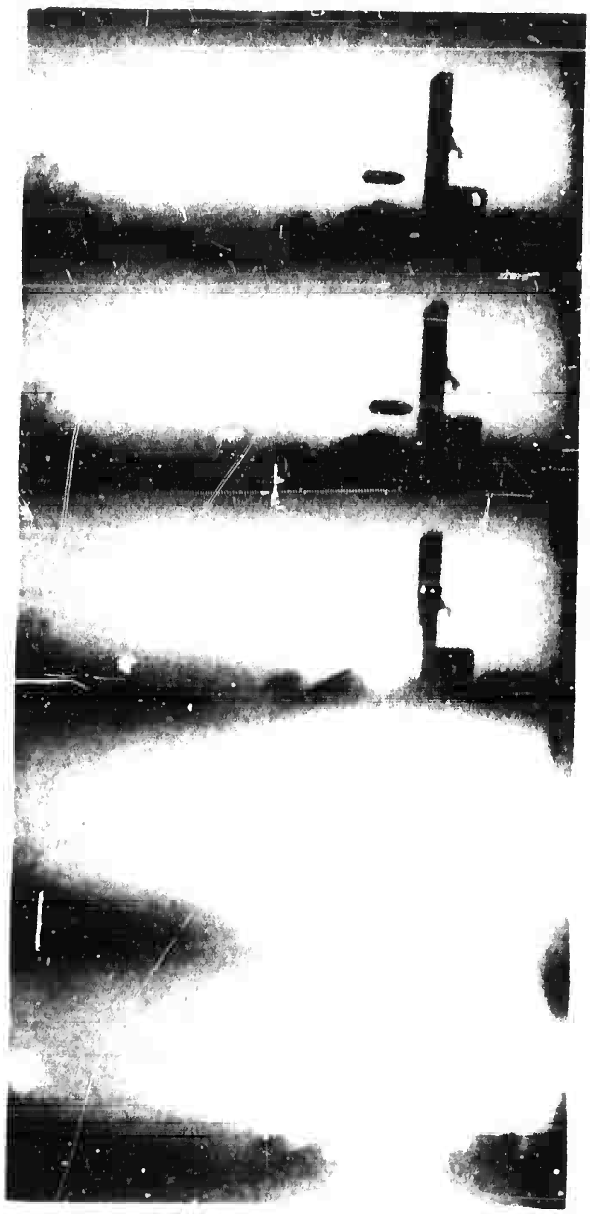

Figure 15: Tube Round 60; Striking Velocity 2566 fps.

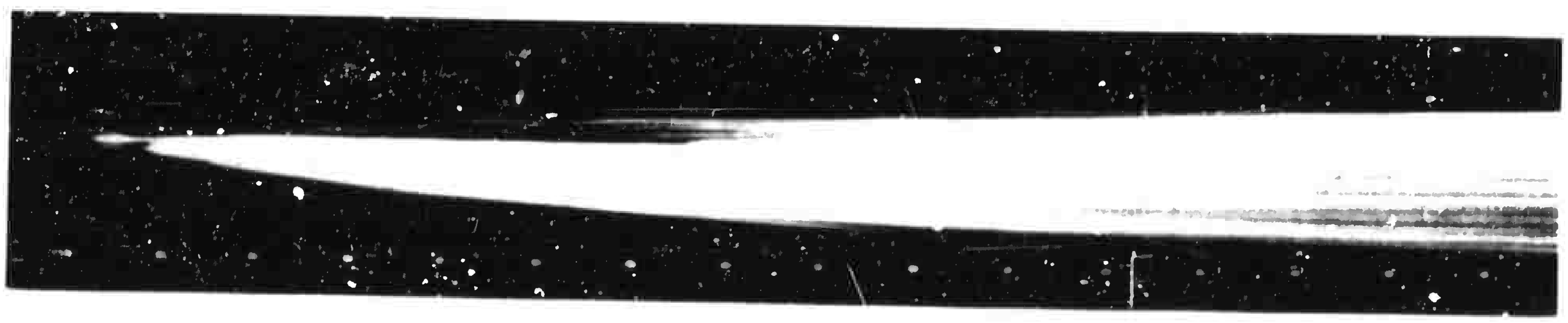

Figure 16: Tube Round 60; Functioning Time 47 Microseconds.

Table II. Functioning Time

Tube Round No.	Striking Velocity, fps	Functioning Time, microseconds: First Indication of Functioning: Camera	Electronic	Main Function (High Order): Camera	Electronic	Remarks
			0° Plate Obliquity			
5	Assumed 2590	-	-	53	Lost	
6	Assumed 2587	-	-	54	100	
7	2530	-	-	54	Lost	Inert-fuzed.
8	2597	-	-	53	80	Inert-fuzed.
9	1721	249	-	408	412	
10	1662	259	-	402	419	
11	1647	243	-	397	Lost	
45	1609	241	244	348	357	
46	1636	205	205	361	364	
47	1656	204	205	752	Lost	Inert-fuzed.
48	1667	194	179	-	-	Inert-fuzed, did not function HO.
49	Assumed 2572	-	-	49	56	
50	Assumed 2582	-	-	Lost	54	
51	Assumed 2580	-	-	Lost	52	
60	2566	-	-	47	65	
			60° Plate Obliquity			
68	2576	113	103	277	Lost	
69	2589	-	-	49	65	
70	2584	129	139	259	292	
72	2589	523	-	1098	Lost	Inert-fuzed.
73	2632	178	-	-	-	Inert-fuzed, did not function HO.
80	984	-	-	738	Lost	Inert-fuzed.
81	2601	131	110	266	287	
82	2626	83	-	266	Lost	
83	2620	144	206	258	260	
84	2634	120	174	257	264	

(C) Table III correlates the average results of this test with "crush-up" (Reference 1). The functioning times used are the average camera times. Inert-fuzed rounds were not considered. All values are average values.

Table III. Results Correlated with Crush-Up

	0° Plate Velocity Levels			60° Plate Velocity Levels		
	1000	1700	2600	1000	1700	2600
First Indication of Functioning						
Number of rounds considered	-	5	-	-	-	6
Time, microseconds	-	239	-	-	-	120
Crush-up distance for first function, inches	-	4.8	-	-	-	3.7
Main Function						
Number of rounds considered	5	5	4	5	5	7
Time, microseconds	297	383	51	372	298	261
Crush-up distance for main function, inches	3.5	7.8	1.75	4.1	5.8	8.0
Spall Energy (Main Spall)						
Number of rounds considered	3	4	-	-	5	4
Average energy (ft-lb)	19,400	42,200	-	-	16,300	14,000
Spall Producing Rounds / Total Rounds	6/6	5/5	0/6	0/5	5/5	5/7[a]

[a]One round not considered due to unfair hit above brace.

(C) Table III indicates the following facts:

a. Even though good spalling was observed at the 1000-fps velocity level against 0° plate, the functioning time was too short. The effect of the short crush-up distance is shown in Figures 17 and 18. These figures show that a great deal of weight is being left on the plate in the form of hinged edges (hinges are outlined in chalk). It appears that the explosive is spread out but not in a sufficient quantity and the hinged edges are the result. This condition occurred on three out of six rounds fired at this velocity level.

b. Although there was low-order nose functioning present at the 1700 fps velocity level against 0° plate, the spall energy is vastly superior to any of the other conditions of velocity level and plate obliquity.

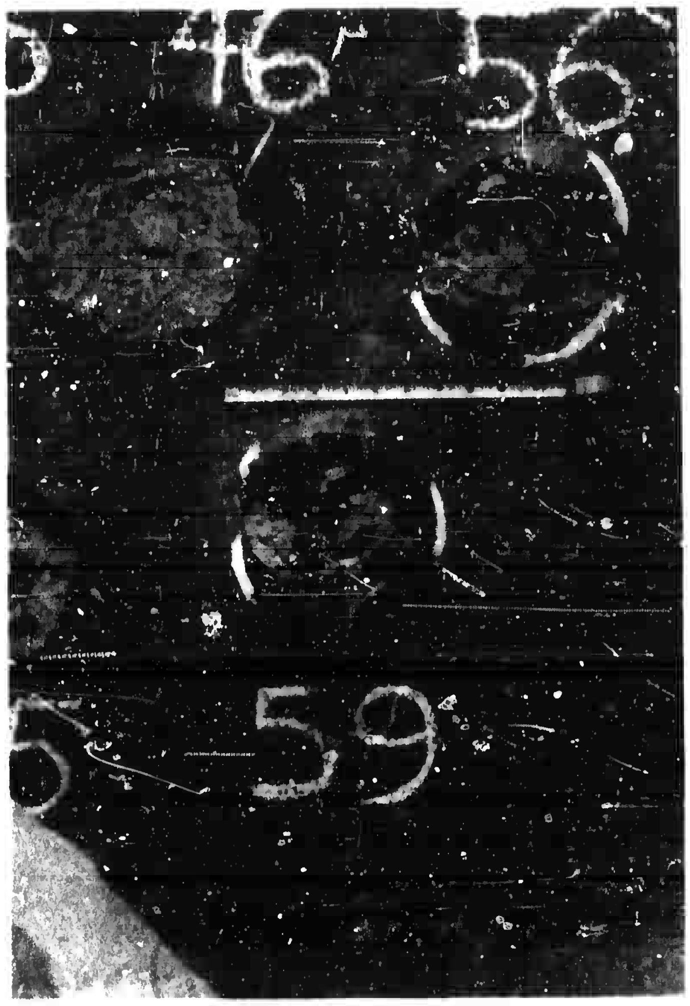

Figure 17: Spall Areas. Note Chalk Marks which Denote Point of Hinge. Head-on View.

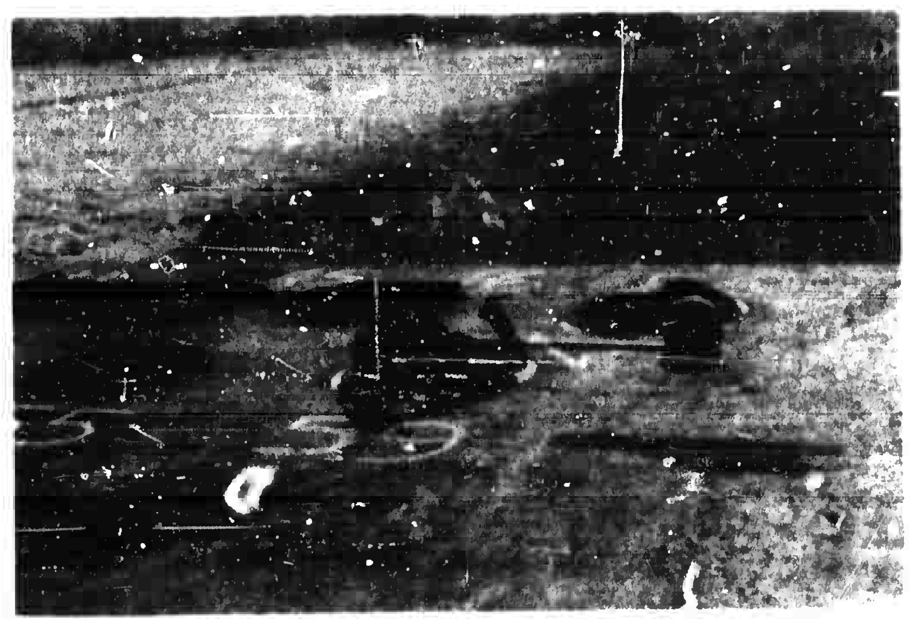

Figure 18: Spall Areas. Note Chalk Marks which Denote Point of Hinge. Viewed from Side.

c. At a velocity level of 2600 fps against 0° plate and a velocity level of 1000 fps against 60° plate the round is useless. At the 0° condition the round is nose initiated high order due to the velocity of impact. At the 60° condition the functioning time is too short. The recovered round (Appendix C-10) showed that after crushing up and sliding off the plate there was only a small section of the round which was split open. At only 4.1 inches of crush-up the amount of explosive in contact with the plate is not sufficient to impart enough energy to cause spalling. Even if the functioning time were extended to allow more crush-up the spall production might still be poor due to the crush-up characteristics of the round at this velocity level and plate obliquity.

d. At a velocity level of 1700 fps against 60° plate the spall production was good but the spall energy was low. The round functions at almost the optimum crush-up distance of 6 inches. However, if the functioning time were increased so that the round would function at from 6-1/2 to 7-1/2 inches of crush-up the spall energy might be increased.

e. At a velocity level of 2600 fps against 60° plate the spall production was fair but the spall energy was low. It appears that the functioning time is slightly too long. Also the low-order nose functioning may have a detrimental effect on the spall energy.

(C) Photographs of the flight of the spall (see Appendix C-4 to C-9) show that the spall tumbles a great deal after leaving the plate. It also appears that much more secondary spall is produced when firing at 0° plate than when firing at 60° plate. During the 0° firing the distance from the spalled area to the impact points on the concrete varied between 18 and 19 feet. Therefore the average spall velocity was calculated for a point between 9 and 9-1/2 feet from the rear of the plate. During the 60° firing the distance from the spalled area to the impact points on the celotex varied from 5 to 9 feet. Therefore the average spall velocity was calculated for a point between 2-1/2 and 4-1/2 feet from the rear of the plate. Appendix C-3 also contains pictures of the spalled area of the plate used during this test.

(C) Figures 19 and 20 are examples of the fuze functioning time as pictured on an oscilloscope. Along with giving the functioning time, these pictures also give an indication of the type of functioning (high order, low order, etc.). On Figure 19, point 1 shows the first indication of functioning when the trace starts to rise. The trace starts to rise slowly and then at point 2 the trace rises almost vertically. The slow rise indicates a low-order type functioning while the almost vertical rise indicates a high-order functioning. Figure 20 shows a typical high-order function. The electronic method has the advantage of giving results immediately after the round has been fired. The camera results are more accurate but developing the film requires a certain amount of time. In further testing of this type it would be advisable to use both methods. This will allow a double-check and also make provisions in case one method fails, as occurred during this test when the camera method failed on three rounds.

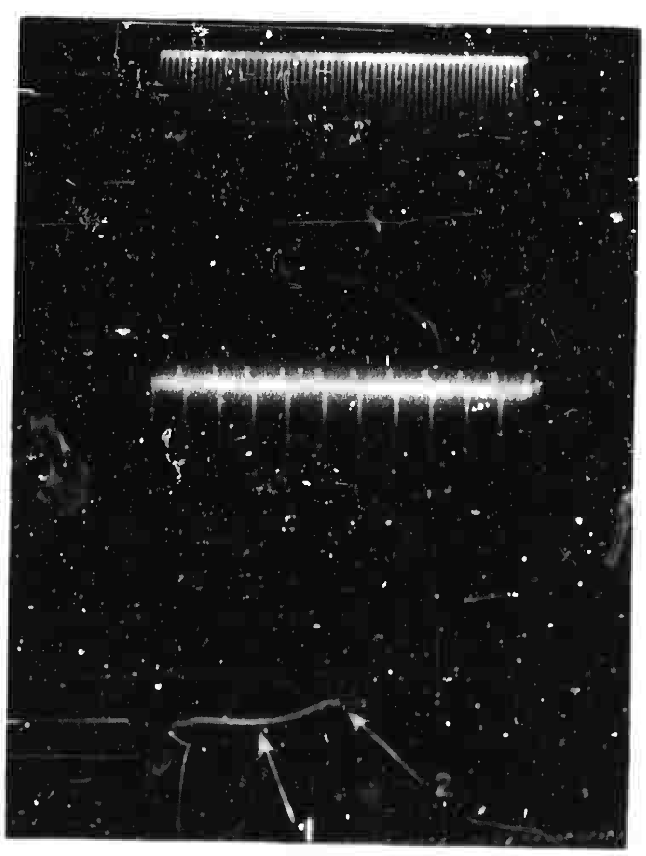

Figure 19: Tube Round 84; Striking Velocity 2582 fps, 60° Plate. Time to First Indication of Functioning - 174 Microseconds; Main Function - 264 Microseconds.

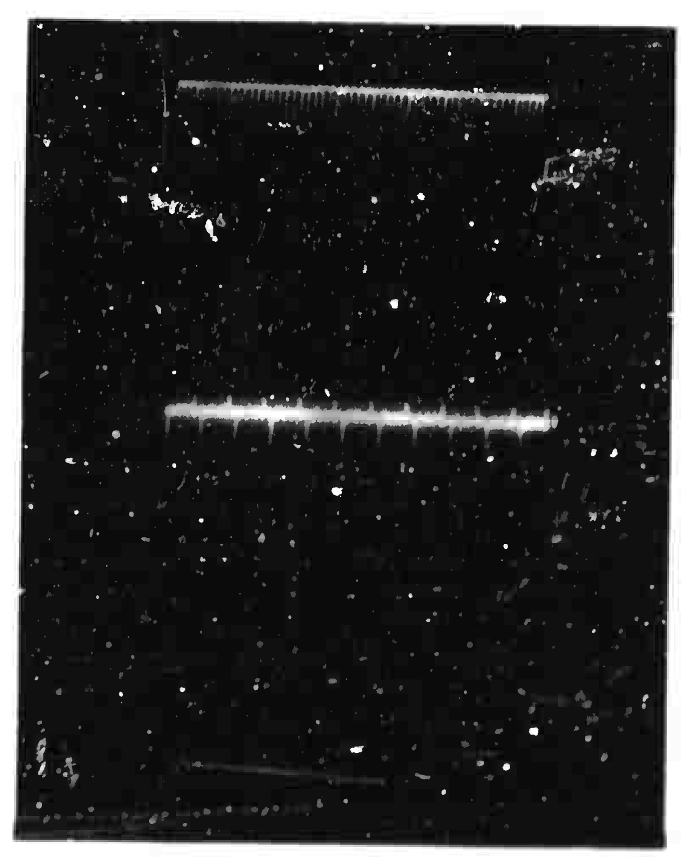

Figure 20: Tube Round 64; Striking Velocity 1642 fps, 60° Plate. Functioning Time -322 Microseconds.

(U) It will be noticed that the results of this test contain some assumed velocities. These velocities were assumed in the following manner. At each velocity level when a velocity was lost, a curve of velocity vs pressure of the other rounds at this level was drawn. On all the rounds when the velocities were lost pressure data had been obtained. By plotting these pressures on the pressure velocity curves a good approximation of velocity was obtained.

(C) In the near future a test similar to this test will be conducted using 90-mm, T142E3, HEP shell containing an inert nose pad. A new fuze, the BD, T303E1 fuze, will also be used in this future test. It is hoped that the inert nose pad will stop the high-order nose initiation which has been experienced at high velocities against 0° plate. The results of this future test will be compared with the results of the present test to determine if any improvement is made in the fuze-functioning time and spall characteristics.

4. (C) CONCLUSIONS

The T142E3, HEP shell, comp A3-loaded and fuzed with a BD, M91A1 fuze is ineffective at velocity levels of 2600 fps against 0° plate and 1000 fps against 60° plate.

The T142E3, HEP shell, comp A3-loaded and fuzed with a BD, M91A1 fuze is most effective when fired at a velocity level of 1700 fps against 0° plate.

5. (C) RECOMMENDATION

It is recommended that development of the T142E3, HEP shell be continued in order to make it effective when fired at velocity levels of 2600 fps or higher against a plate obliquity of 0°.

SUBMITTED:

Laurence R Nealley

LAURENCE R. NEALLEY
Test Director

REVIEWED:

HB Anderson

H. B. ANDERSON
Chief, Artillery
Ammunition Branch

for M. D. Kaplan

H. A. BECHTOL
Chief, Artillery Division

APPROVED:

Arthur Gwood

H. A. NOBLE
for Assistant Deputy Director
for Engineering Testing
Development and Proof Services

REFERENCES

1. Nealley, L. R. Armor Impact Deceleration Characteristics of Inert 90-mm T142E3 HEP Shell. Aberdeen Proving Ground. Project TW-426, March 1959.

2. Nealley, L. R. X-Ray Photographs of Inert 90-mm, T142E3, HEP shell impacting on Armor Plate. Aberdeen Proving Ground. Project TA1-5002H, April 1958.

3. Unpublished report on Plate Test of T303E1 Fuze.

APPENDICES

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APPENDIX A
Directive Correspondence

Department of the Army
Ordnance Corps
Picatinny Arsenal
Dover, N.J.

Mr. T. Clifford/ers/2269

TS5 -472 (T11-5201) -13

SUBJECT: Amendment of Test Program Request T-10 (U)

TO: Commanding General
Aberdeen Proving Ground
Aberdeen, Maryland
ATTENTION: DPS-AA Lt. Giordano

1. Firings conducted at your proving ground under the subject TPR have produced the following results, to date:

a. Satisfactory X-ray photographs of 90mm T142E3 HEP Shell, inert loaded w/inert fuzes, impacting on plate targets at approx. velocities of 1000, 1700 and 2600 FPS with crush-up distances of approx. 2,4,6,8, and 10 inches have been made.

b. It has proven impractical to produce X-ray pictures of live loaded and live fuzed 90mm HEP Shell on target impact due to the resulting high velocity shell fragments destroying the X-ray equipment.

3. In view of the above facts it has become necessary to amend and clarify further work to be conducted under the subject TPR as follows:

a. Funds are available under Sub-Project Order No. 70405530-01-10201 and Job Order No. 3039-99-901.

b. Fire sufficient 90mm, T142E3 HEP Shell against 4" thick homogeneous armor, having a Charpy impact value of 35 to 50 Ft. Lbs. at $-40^{\circ}F$, set at 60° obliquity and approx. 200 ft. range from the 90mm Gun T119 or M41, to produce 4 clear X-ray pictures of 4 each of the following shell crush-up distances on impact; 2", 4", 6", 8" at the following muzzle velocities; 1000, 1700, and 2600 FPS. Total 48 X-ray photographs. For clarity this test should be referred to as "Part 2, Test 1". One hundred 90mm, T142E3 HEP Shell, inert loaded with inert fuzes for use in the above test are scheduled for shipment, from this Arsenal, to your Proving Ground the week of 5 August 1957.

c. The following three lots of live loaded and live fuzed shell with inert nose pads, now at your Proving Ground, should have the live fuzes removed and have inert M191A1 Fuzes assembled thereto and be fired against 4" thick, 60° obliquity plate at 2600 FPS velocity. All possible X-ray photographs of 2", 4", 6" and 8" crush-up should be obtained.

REGRADING DATA CANNOT BE PREDETERMINED

CONFIDENTIAL

ORDBB-T-5
SUBJECT: Amendment of Test Program Request TR-10 (U)

(1) 7 Shell, HEP, 90mm, T142E3 Comp A3 Loaded, Lot PA-E-24406.

(2) 14 Shell, HEP, 90mm T142E3, 75/25 Octol Loaded, Lot PA-E-21587.

(3) 7 Shell, HEP, 90mm T142E3 Comp B Loaded, Lot PA-E-21589.

Inert fuzes and fuze gas checks will be supplied by this Arsenal for the above modification. For clarity this phase should be referred to as "Part 2, Test 2".

3. At the conclusion of Part 2 Tests 1 & 2, as outlined above, Part 3 outlined below should be fired:

a. Fire sufficient, 90mm T142E3, live loaded and live fuzed shell, (suggest 5 each condition min.) against plate targets and record time of fuze functioning. Target should be 4" thick homogeneous armor, Charpy Impact value of 35 to 50 Ft. Lbs. at -40°F.

Target Obliquity	Velocity	No. Rds.
0°	1000 FPS	5 approx.
0°	1700 FPS	"
0°	2600 FPS	"
60°	1000 FPS	"
60°	1700 FPS	"
60°	2600 FPS	"

Record size of facial impression and size, weight and velocity of spall.

b. Fuze functioning time should be measured as the time interval between the shell touching the target and initiation of the detonation. In previous tests, streak cameras have been successfully used for this type recording.

4. The time of fuze functioning will be used in conjuction with crush-up X-rays, from Part 1 and 2, in order to determine the shell configuration at time of fuze functioning. It is planned to utilize this data to design HEP shell metal parts which will produce more optimum crush-up shapes at time of detonation. These experimental shell will be tested for crush-up and fuze functioning following the procedure currently in use for the 90mm T142E3 test vehicle.

FOR THE COMMANDER:

CC
OCO ORDTA
Chamberlain Corp, 100 Mildred St,
Waterloo, Iowa, ATTN: Mr. I. Herman
APG, Comptroller's Office

APPENDIX B

Firing Record

DEVELOPMENT AND PROOF SERVICES
ABERDEEN PROVING GROUND, MARYLAND
FIRING RECORD

Investigation of Functioning and Spalling Characteristics of the 90-mm, T142E3, HEP Shell, Comp A3-Loaded, and Fuzed with BD, M91A1 Fuzes (U)

Firing Record No.: P-64115
Dates of Test: 23 October to 25 November 1958
Authority: ORDBB-TE5/TE-10 Amend 1

Project No.: TW-426
Development Test
Related Firing Record: P-62943

W. O. No. 332-236-57 v1

ITEM UNDER TEST (U)

The item under test was the standard 90-mm, T142E3, HEP shell, Comp A3-loaded and fuzed with a M91A1, BD fuze.

SUPPORTING FACILITIES AND MATERIALS

Ammunition Components (U)

Projectile:	Shell, HEP, 90-mm, T142E3, comp A3-loaded, Lot PA-SR-11.
Propellant:	MP, M1, Lot 11108, web 0.0290 inch.
	MP, M1, Lot 35954, web 0.0238 inch.
	MP, M1, Lot 33055, web 0.0211 inch.
Primer :	T70, 300 grains, Lot KOP-49-1.
Case :	90-mm, T24B1, Lot NOR-11-5.
Fuze :	BD, M91A1, Lot PA-457-8.
	BD, M91A1, inert loaded, Lot PA-E-X25004.

Weapon (U)

Gun :	90-mm, T139, No. 10140.
Tube :	90-mm, T139, No. 45569.
Recoil:	155-mm, No. 2882.
Mount :	Gun Motor Carriage, M40.

Armor Plate (C)

Kind : Rolled homogeneous.
No. : 0147611-A and 0147611-A1.
Size : 4 by 72 by 72 inches.
Average Bhn : 266.
Charpy Value: 38 to 40 at -40°F.

Ladle Analysis, %

C	Mn	P	S	Si	Ni	Cr	Mo
0.28	0.25	0.010	0.025	0.26	3.57	1.51	0.43

Used with tube rounds 5 through 11, 45 through 60, and 74 through 84.

Kind : Rolled homogeneous.
 : 080839A2.
Size : 4 by 72 by 72 inches.
Average Bhn : 275.
Charpy Value: 43 to 45 at -40°F.

Ladle Analysis, %

C	Mn	P	S	Si	Ni	Cr	Mo
0.28	0.25	0.010	0.025	0.26	3.57	1.51	0.43

Used with tube rounds 60 through 73.

Instrumentation (U)

Velocity Measurement:

Velocities were measured by the use of thirty-inch solenoid coils and a counter chronograph.

Pressure Measurement:

Pressures were measured by using two medium caliber M3 gauges placed in the base of each case.

Cameras:

A 16-mm smear camera was used to record the fuze-functioning time.

An 8-mm framing camera with a framing rate of 10,000 frames per second was used to record the projectile impact.

A 16-mm framing camera with a framing rate of 4000 frames per second was used to record the flight of the spall.

ROUND-BY-ROUND DATA (C)

Round No. Tube	Round No. Test	Weight, lb	Velocity, fps Muzzle	Velocity, fps Striking	Pressure, psi/100	Type of Fuze Filler	Facial Impression, inches Hor	Facial Impression, inches Vert	Facial Impression, inches Depth	Spall Area, inches Hor	Spall Area, inches Vert	Spall Area, inches Depth	Major Spall* Number of Pieces	Major Spall* Weight of Recovered, lb	Major Spall* Avg Vel, fps	Major Spall* Kinetic Energy, ft-lb	Functioning Time, microseconds Camera	Functioning Time, microseconds (See Note 5) Electronic	Remarks
23 October 1958				Plate at 0° obliquity.			Gun to First Coil - 55.90 feet; First to Second - 95.75 feet; Gun to Plate - 210.30 feet.												
5	40	16.00	Lost	Assumed 2590	25.9	Live	See Note 2.										53	Lost	Nose initiated.
6	16	15.94	Lost	Assumed 2587	25.7	Live	See Note 2.										54	100	Nose initiated.
24 October 1958				Plate at 0° obliquity.			Coil distances same as previous day.												
7	93	15.90	2574	2530	25.8	Inert	See Note 2.										54	Lost	Nose initiated.
8	57	15.94	2641	2597	26.1	Inert	See Note 2.										53	80	Nose initiated.
9	5	15.97	1755	1721	12.7	Live	8 diameter		3/8	8-1/2	8-1/4	1	1 Recovered 1 Missing	1.68	561		408	412	
10	97	16.02	1696	1662	10.6	Live	8 diameter		3/8	8	7-3/4	1	2	7.54	595	41,200	402	419	
11	85	15.93	1681	1647	10.1	Live	8 diameter		3/8	8-1/2	6-1/2	1	3	7.57	655	50,400	397	Lost	
12 November 1958				Plate at 0° obliquity.			Gun to First Coil - 57.55 feet; First to Second - 55.10 feet; Gun to Plate - 209.52 feet.												
45	-	16.04	1642	1609	9.6	Live	6 diameter		3/8	7-3/4	9	1-1/2	2	7.62	563	36,300	348	257	
46	82	16.00	1673	1636	9.6	Live	7-1/2 diameter		1/2	8-1/4	7-3/4	7/8	2	7.20	604	40,800	361	364	
47	63	15.99	1656	1623	9.2	Inert	See Note 3.										752	Lost	
48	59	15.92	1667	1634	9.3	Inert	See Note 3. Some burning but did not function high order.										-	-	
49	2	16.00	Lost	Assumed 2572	24.9	Live	See Note 2.										49	56	Nose initiated.
13 November 1958				Plate at 0° obliquity.			Gun to First Coil - 57.48 feet; First to Second - 55.24 feet; Gun to Plate - 209.52 feet.												
50	37	15.98	Lost	Assumed 2582	25.4	Live	See Note 2.										Lost	54	Nose initiated.
51	46	16.00	Lost	Assumed 2580	25.3	Live	See Note 2.										Lost	52	Nose initiated.
52	68	16.00	1011	1001	6.0	Live	6-1/2 diameter		1/2	6-1/2	7	7/8	1	5.68	Lost	-	Lost	336	
53	22	16.03	989	979	-	Live	6-3/4 diameter		1/2	6-3/4	7	7/8	2	6.56	476	23,000	308	342	
54	58	16.06	994	984	-	Live	7 diameter		1/2	6	6-3/4	7/8	1	3.84	567	19,200	307	351	
55	33	15.98	998	988	-	Live	6-1/2 diameter		1/2	6-3/4	6	3/4	2	5.44	470	16,100	298	339	
56	53	16.03	973	965	-	Live	6 diameter		1/2	6-1/2	5	3/4	2 Recovered 1 Missing	1.85	738 514 416	-	298	340	
57	79	15.97	1001	991	-	Inert	Very small amount of burning. Explosive scattered around butt.										Did not function	-	
58	77	15.95	1001	991	5.0	Inert	Very small amount of burning. Explosive scattered around butt.										Did not function	-	
59	73	16.02	998	988	-	Live	6 diameter		1/2	5-3/4	4	1	1 Not Recovered	-	406	-	276	285	
60	4	16.00	2611	2566	25.0	Live	See Note 2.										47	65	

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Round No. Tube	Round No. Test	Weight, lb	Velocity, fps Muzzle	Velocity, fps Striking	Pressure, psi/100	Type of Fuze Filler	Facial Impression, inches Hor	Facial Impression, inches Vert	Facial Impression, inches Depth	Spall Area, inches Hor	Spall Area, inches Vert	Spall Area, inches Depth	Major Spall* Number of Pieces	Major Spall* Weight of Recovered, lb	Major Spall* Avg Vel, fps	Major Spall* Kinetic Energy, ft-lb	Functioning Time, microseconds (See Note 5) Camera	Functioning Time, microseconds (See Note 5) Electronic	Remarks
19 November 1958				Plate at 60° obliquity.			Gun to First Coil - 58.25 feet; First to Second - 55.28 feet; Gun to Plate - 221.53 feet.												
61	100	15.92	Lost	Assumed 1638	9.6	Live	7-3/4	9-3/4	1/2	6	7-3/4	1-3/8	1	8.12	379	18,100	324	363	
62	88	15.95	1695	1658	10.2	Live	7-1/2	10	1/2	6	7-3/4	1-1/4	1	7.24	389	17,000	311	347	
63	89	16.02	1686	1650	10.4	Live	7	9-1/4	3/8	6-1/2	7-1/2	1-1/4	1	7.82	271	8,900	294	330	
64	94	16.03	1642	1607	9.3	Live	7	9-1/2	3/8	6	7-1/2	1-1/8	1	7.30	419	19,900	237	322	
24 November 1958				Plate at 60° obliquity.			Coil distances same as for 19 November.												
65	35	16.02	1659	1659	9.7	Live	7-1/2	9-1/2	3/8	5-1/2	6-3/4	1-1/4	1	6.08	432	17,600	273	Lost	
66	87	15.96	1686	1686	9.9	Inert	No detonation or burning. Small amount of plate flash.										Did not function	-	
67	96	15.88	1688	1688	9.6	Inert	No detonation or burning. Small amount of plate flash.										Did not function	-	
68	92	16.03	2624	2575	25.1	Live	6-1/2	7-1/2	3/8	5	5	Hinged out 1-1/2	Slight overlap on tube round 65.				277	Lost	Hinged from 11 [illegible] o'clock.
69	101	16.02	2637	2589	25.8	Live	See Note 4.										49	65	
70	19	16.00	2632	2584	26.1	Live	7	9-1/2	3/8	6-1/4	7	7/8	1	7.62	Lost	-	259	292	
71	48	16.04	2651	2603	25.7	Live	8	10-1/2	3/8	6	8-1/2	1	1	8.66	359	15,200	242	272	
72	84	15.96	2637	2589	25.9	Inert	No facial impression. Large ball of fire observed.										1098	Lost	
73	15	15.95	2632	2584	25.2	Inert	No facial impression. Large ball of fire observed.										-	Lost	Did not function [illegible] order.
25 November 1958				Plate at 60° obliquity.			Coil distances same as previous day.												
74	96	16.01	Lost	Assumed 990	5.1	Live	6	8-1/2	3/8	4-1/2	6	Bulged out 7/8	-	-	-	-	338	Lost	Bulge cracked from 4 to 11 o'clock.
75	60	15.92	992	981	-	Live	5-3/4	8-1/4	3/8	4-1/2	6	Bulged out 3/4	-	-	-	-	388	Lost	Bulge cracked from 7 to 10 o'clock.
76	51	15.97	990	979	-	Live	6	8-1/2	3/8	4-3/4	6	Bulged out 7/8	-	-	-	-	403	Lost	Bulge cracked from 4 to 9 o'clock.
77	12	15.94	988	977	-	Live	6	8-1/2	3/8	5	6-1/2	Bulged out 3/4	-	-	-	-	385	418	Bulge cracked from 5 to 8 o'clock.
78	6	16.00	1010	998	-	Live	5-3/4	8-1/4	3/8	4-3/4	6	Bulged out 3/4	-	-	-	-	348	384	Bulge cracked from 4 to 9 o'clock.
79	64	15.95	993	982	-	Inert	No detonation or burning.										Did not function	-	
80	8	15.92	984	973	-	Inert	6-3/4	9-3/4	1/4	No indication of bulge on rear of plate.							738	Lost	
81	67	16.05	2601	2550	24.0	Live	7	9-1/2	1/4	6-1/2	7-1/2	1	1	-	-	-	266	287	See Note 1.
82	43	15.96	2626	2574	24.4	Live	8	10	1/4	6-3/4	8-3/4	1	1	8.94	371	19,100	266	Lost	
83	36	15.98	2620	2568	24.8	Live	7-3/4	10	1/4	6-1/2	8-1/2	1	2	9.10	312	13,800	258	260	
84	50	15.96	2634	2582	25.1	Live	8	10	1/4	5-1/2	7-1/4	3/4	1	7.64	256	7,800	257	264	

* Recovered spall identified as part of original face of plate (rear). No secondary spall was recovered.

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Notes:

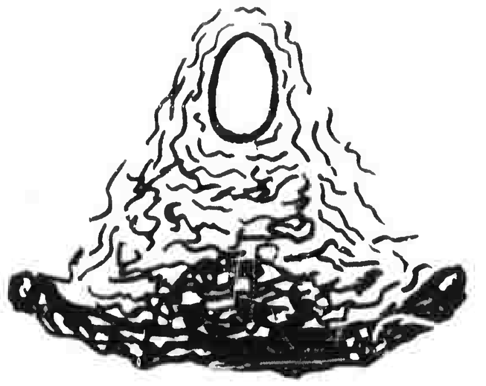
1. On tube round 81, the round impacted above a 12- by 12-inch brace. The spall started to come off the plate but was held back by the edge of the brace.

2. This round functioned from the nose. The following sketch shows the facial impression.

The diameter of the small circle in the center was from 3 to 3-3/4 inches. It was "dished" out to a depth of 1/4 inch. The surface of the small circle was fairly smooth. From the edge of the small circle to a diameter of 7-1/4 to 8 inches the area was "washed" and was very rough and uneven. The whole area of approximately 8 inches in diameter was yellowish in color. At a radius of approximately 16 to 17 inches from the center of the small circle there was a ring of fragmentation marks. The ring of fragmentation or "pock" marks consisted of two distinctly different types of marks. One type of mark was caused by the impact of copper fragments from the rotating band. These marks were copper colored and had very little if any depth to them. The other marks were caused by steel fragments and were gouged out to a depth of about one-eighth of an inch. One other noticeable feature of this ring of pock marks was the fact that the two types of marking were distributed in an alternating pattern. First there would be a copper mark, a steel mark, perhaps two copper marks, a steel mark, a copper mark, etc. The copper marks ranged from 1 to 2 inches in length while the steel marks were 2 to 3 times as long as the copper marks.

3. The facial impression on this round consisted of a small circle approximately three inches in diameter which was yellowish in color. There was no depth to this impression. Both rounds functioned at what appeared to be burning type of functioning which eventually went high order.

4. The facial impression for this round is shown in the following sketch.



The dimensions of the oval were: vertical 4-1/2 inches and horizontal 3 inches. The oval was dished out slightly and was quite smooth. The rest of the area was heavily washed and gouged especially when the base impacted against the armor.

5. The fuze functioning times as determined by the electronic method are not as accurate as the times which were determined by the camera method due to the fact that the electronic method is still in the experimental stages.

6. The following propelling charges were used during this test:

Eighty ounces of Lot 11108 for all rounds fired at the 2600 fps velocity level.

Thirty-six ounces of Lot 35954 for all rounds fired at the 1700 fps velocity level.

Thirteen and three-quarter ounces of Lot 33055 for all rounds fired at the 1000 fps velocity level.

This firing record forms a part of the Fourth Report on Ordnance Project No. TW-426.

SUBMITTED:

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Test Director

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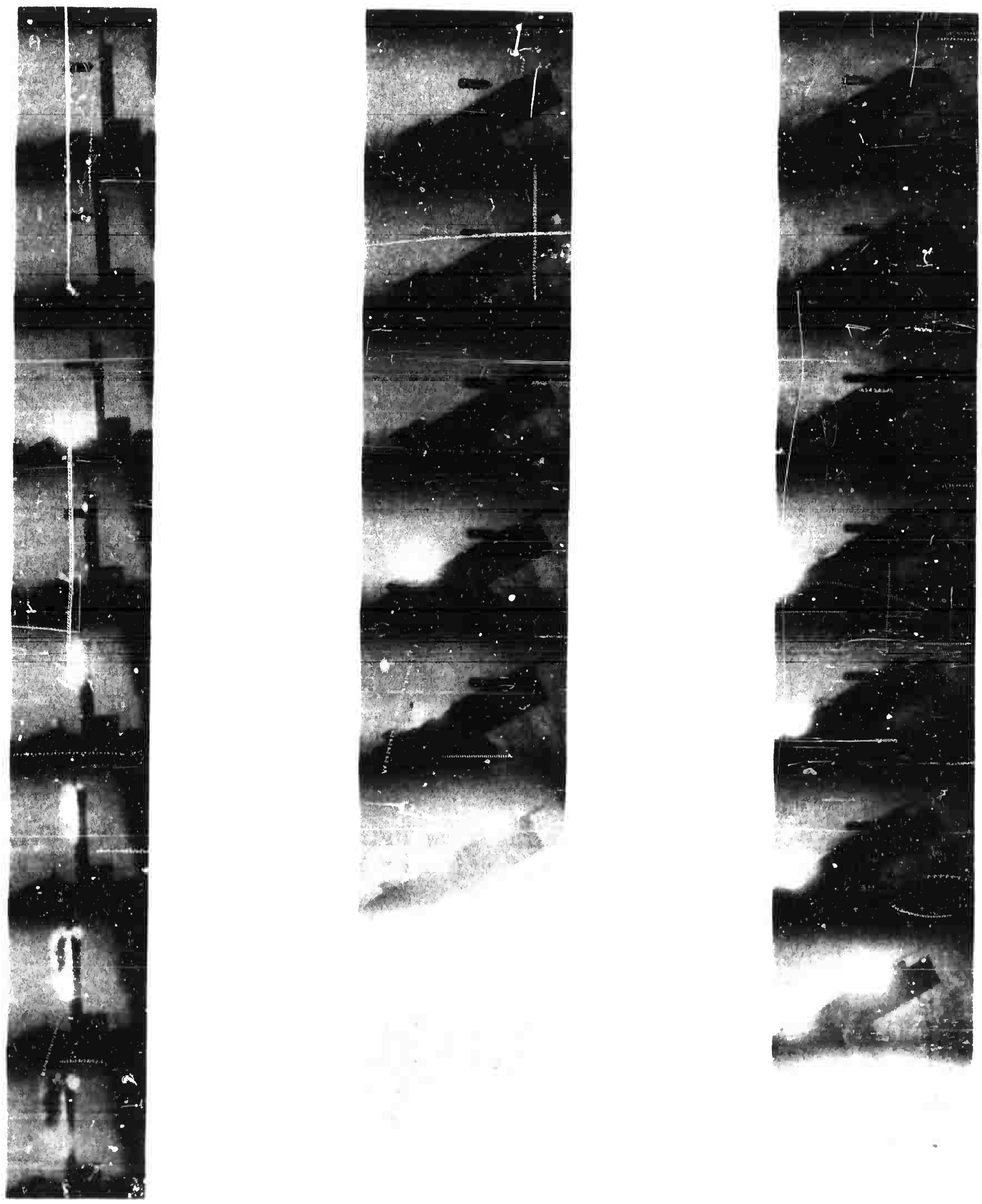
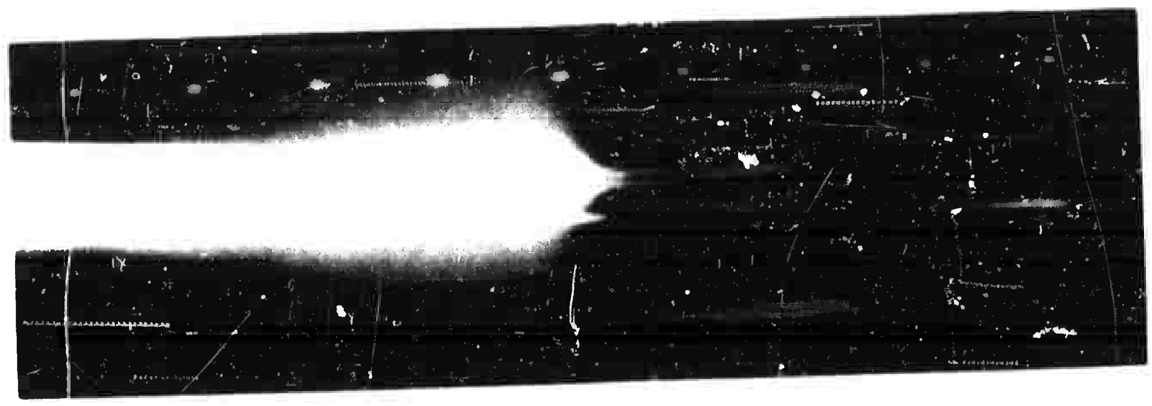
H B Anderson
H. B. ANDERSON
Chief, Artillery
Ammunition Branch

APPROVED:

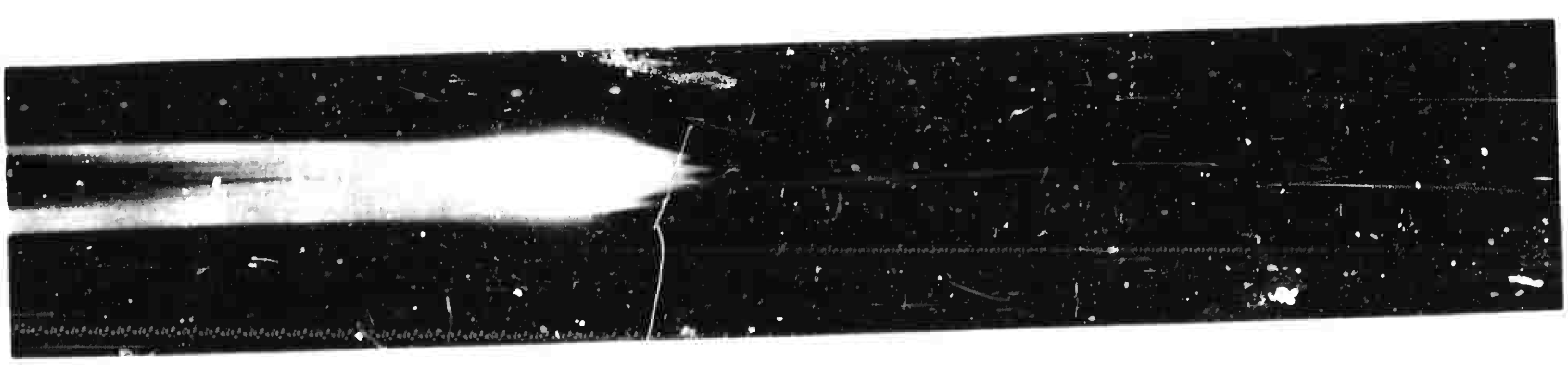
M. D. Kaplan
for H. A. BECHTOL
Chief, Artillery Division



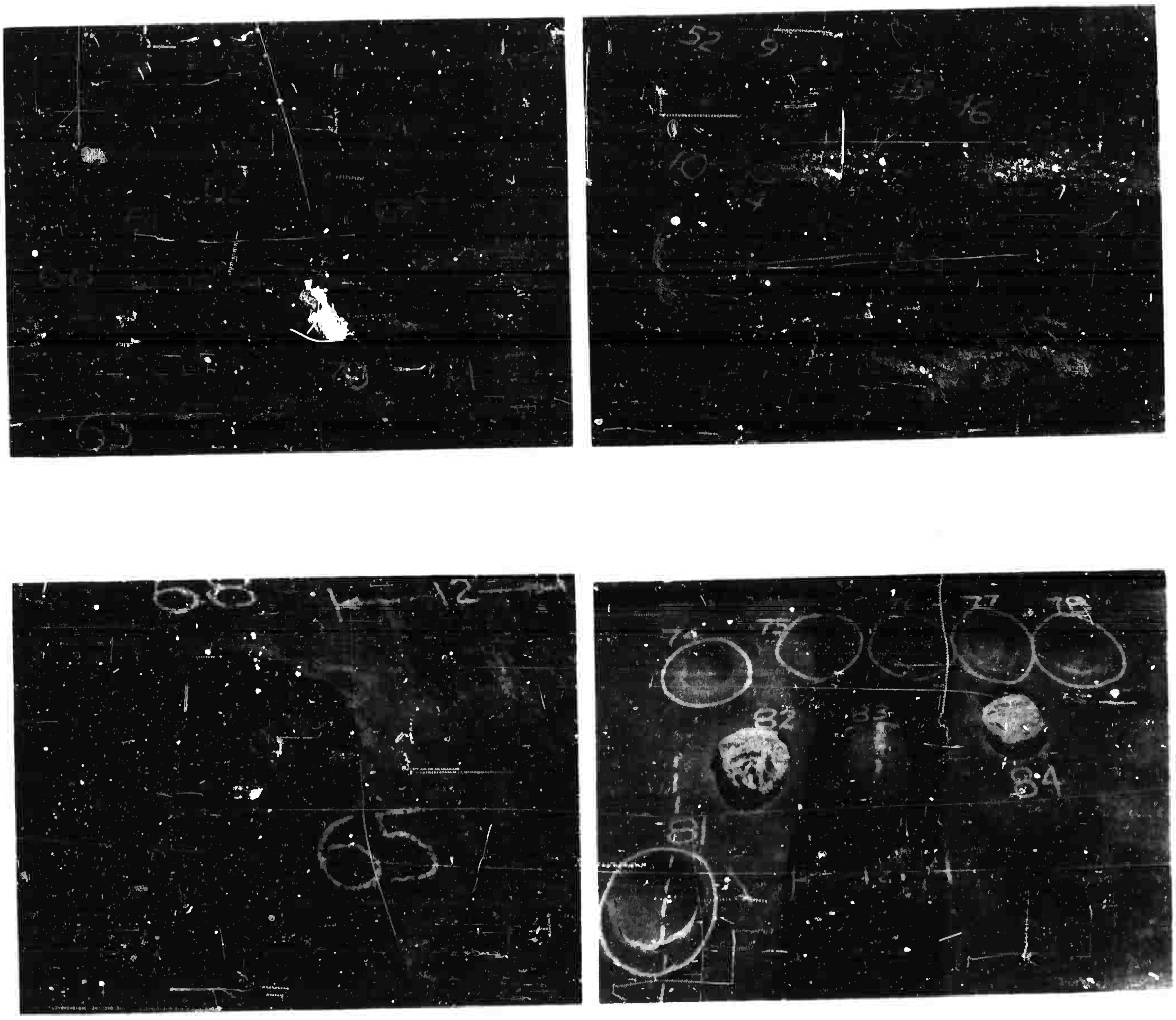
Impact Photos of Tube Round 48 (Left), Striking Velocity 1667 fps; Tube Round 64 (Center), Striking Velocity 1607 fps; and Tube Round 75 (Right), Striking Velocity 981 fps.



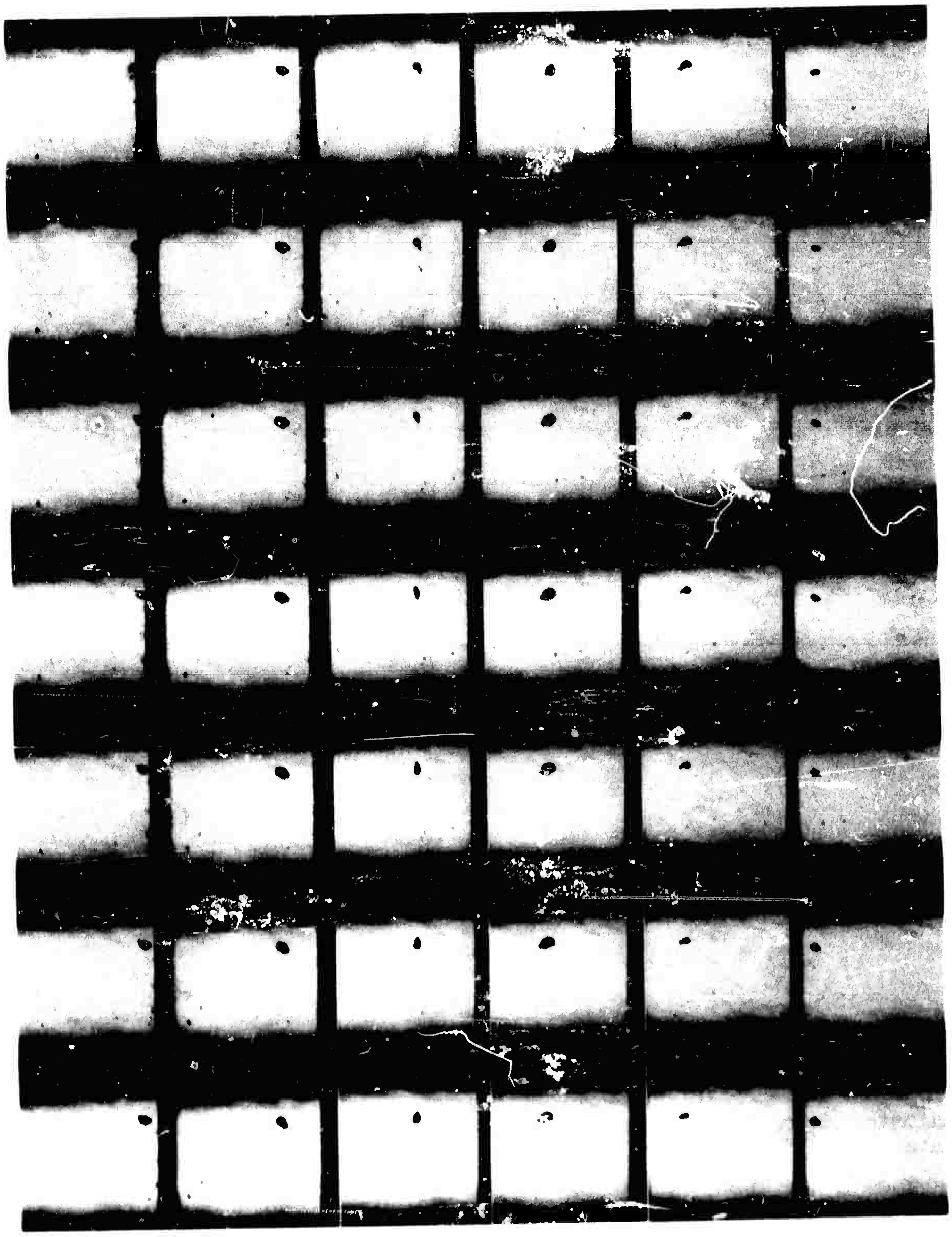
Impact Photo and Fuze-Functioning Time Print for Tube Round 46, Striking Velocity 1636 fps; Time to First Indication of Functioning 205 Microseconds; Main Function 361 Microseconds.



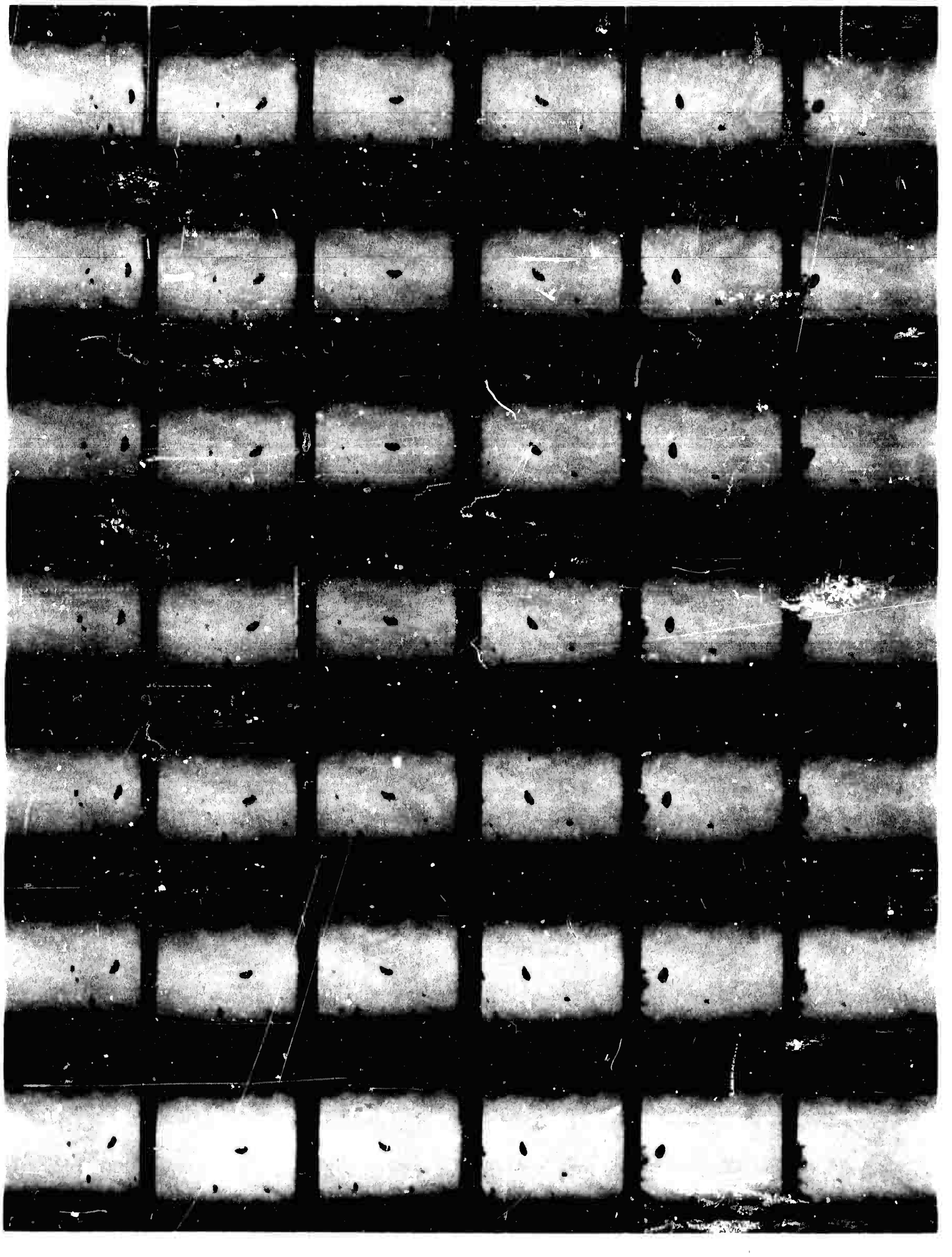
Fuze-Functioning Time Print for Tube Round 47, Inert-Fuzed, 0° Plate; Striking Velocity 1623 fps; Time to First Indication of Functioning 204 Microseconds; Main Function 752 Microseconds.



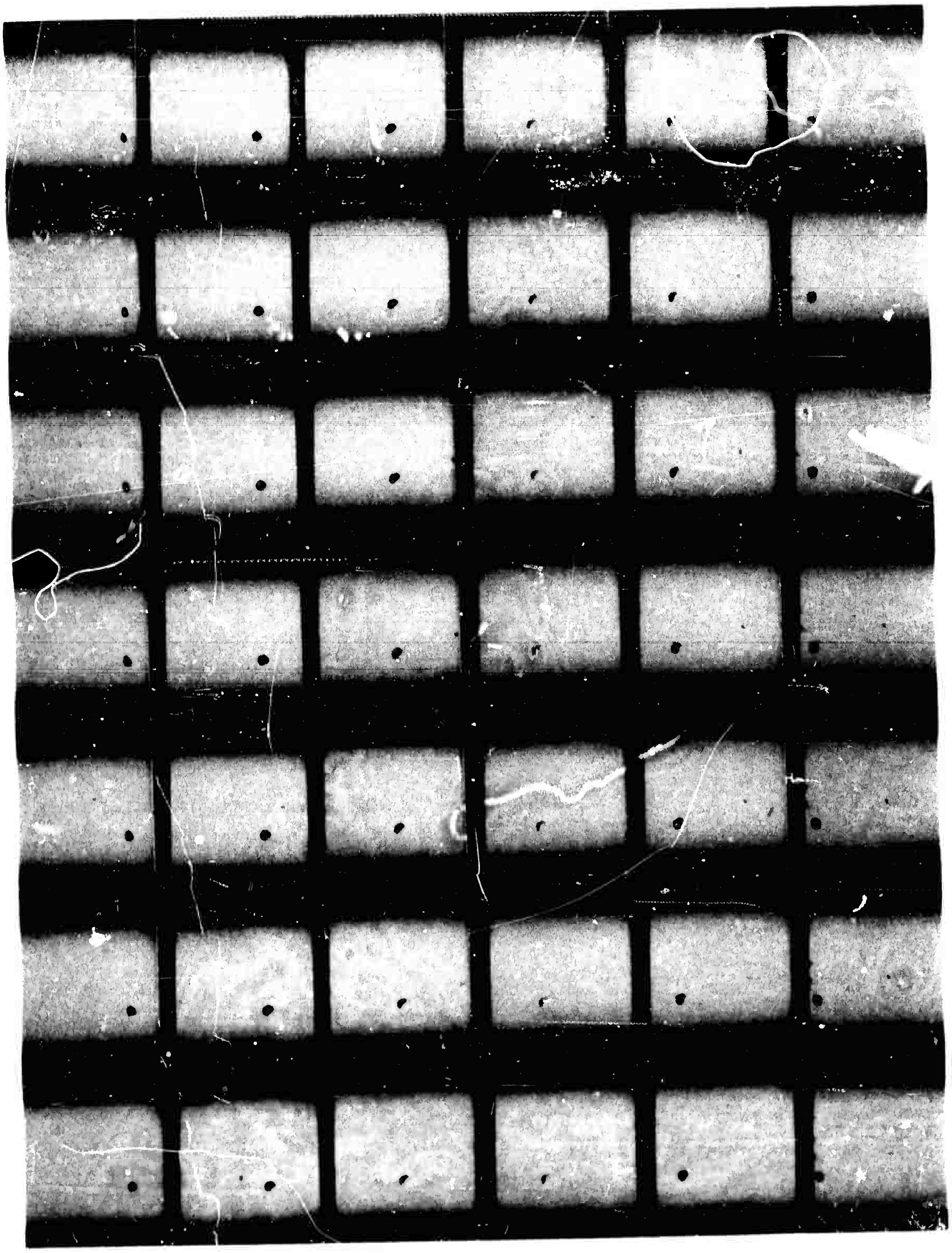
Spall Areas of Plates Used During Test. Dotted Line in Lower Right Photo Indicates Where Edge of 12- by 12-Inch Brace Stopped Spall from Coming Off the Plate.



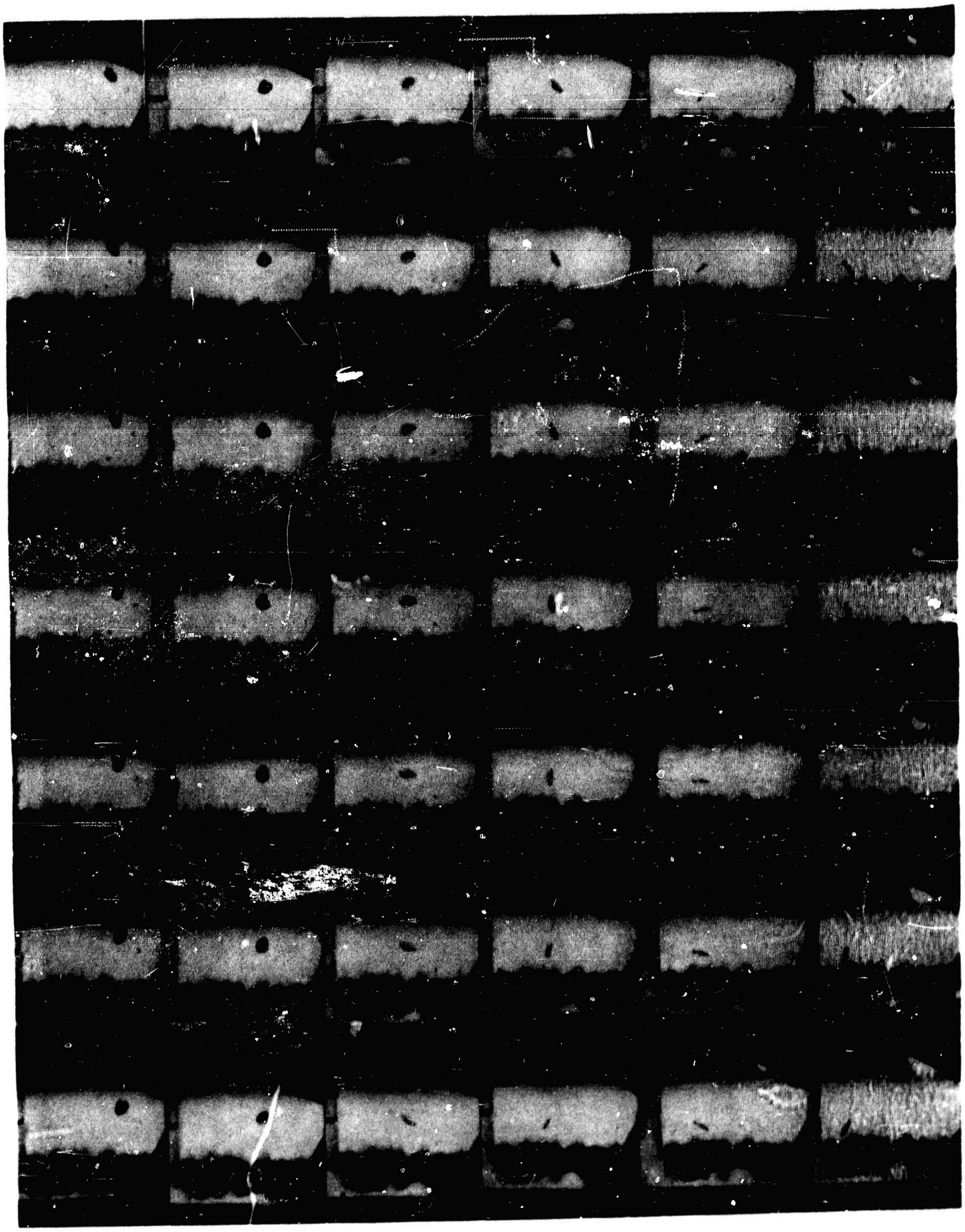
Flight of Spall which was Initiated by Tube Round 46. Plate Obliquity 0°; Round Striking Velocity 1636 fps; Spall Velocity 604 fps; Spall Weight 7.20 lb, Spall Energy 40,800 ft-lb. Note the Flight of Secondary Spall and Impact of Secondary and Major Spall Against Concrete Block.



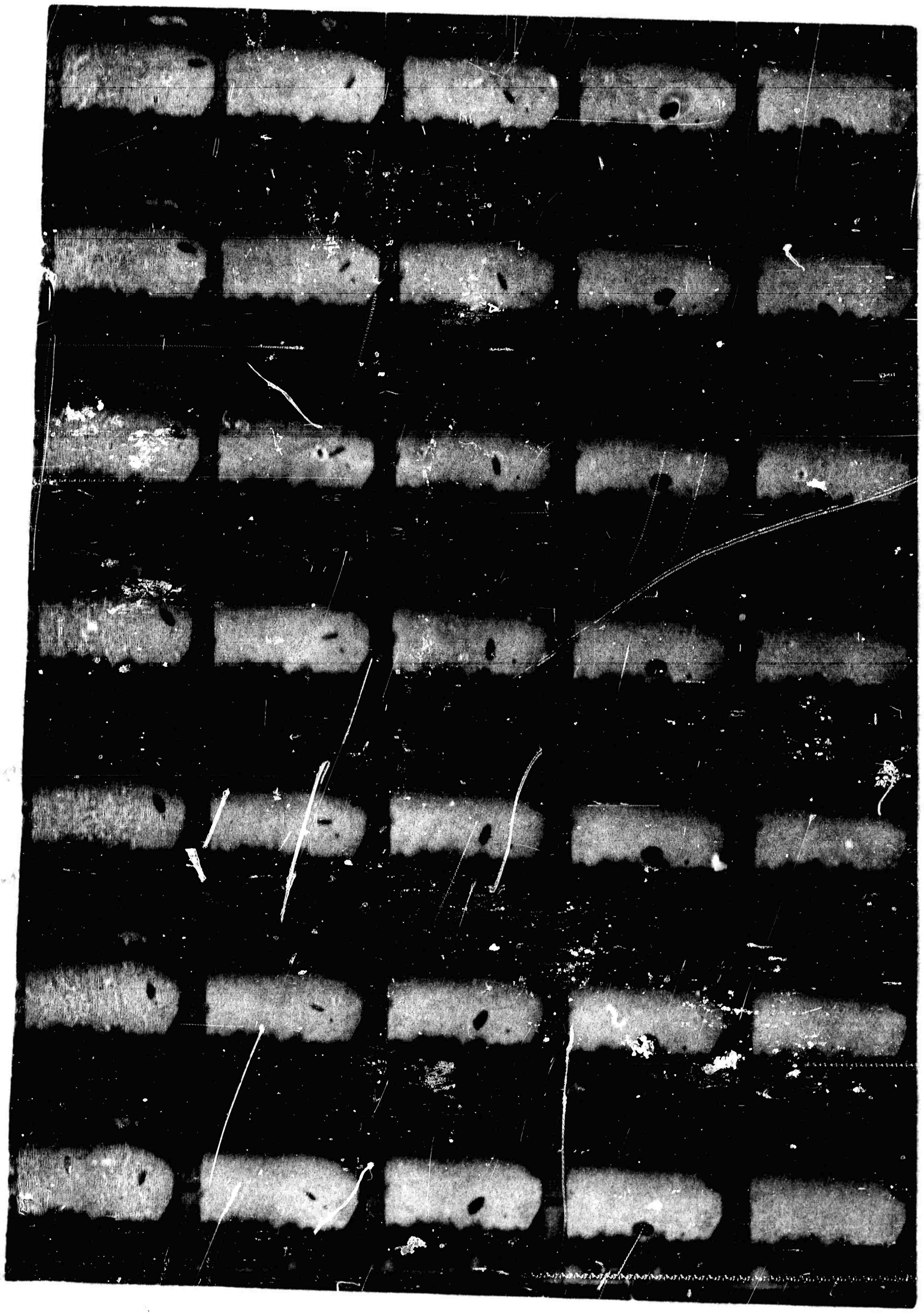
Flight of Spall which was Initiated by Tube Round 45. Plate Obliquity 0°; Round Striking Velocity 1609 fps; Spall Velocity 5.63 fps; Spall Weight 7.62 lb; Spall Energy 36,300 ft-lb. Note the Flight of Secondary Spall and Impact of Secondary and Major Spall Against Concrete Block.



Flight of Spall which was Initiated by Tube Round 54. Plate Obliquity 0°; Round Striking Velocity 984 fps; Spall Velocity 567 fps; Spall Weight 3.84 lb; Spall Energy 19,200 ft-lb. Note that the Amount of Secondary Spall is Considerably Less than in the Two Previous Cases.

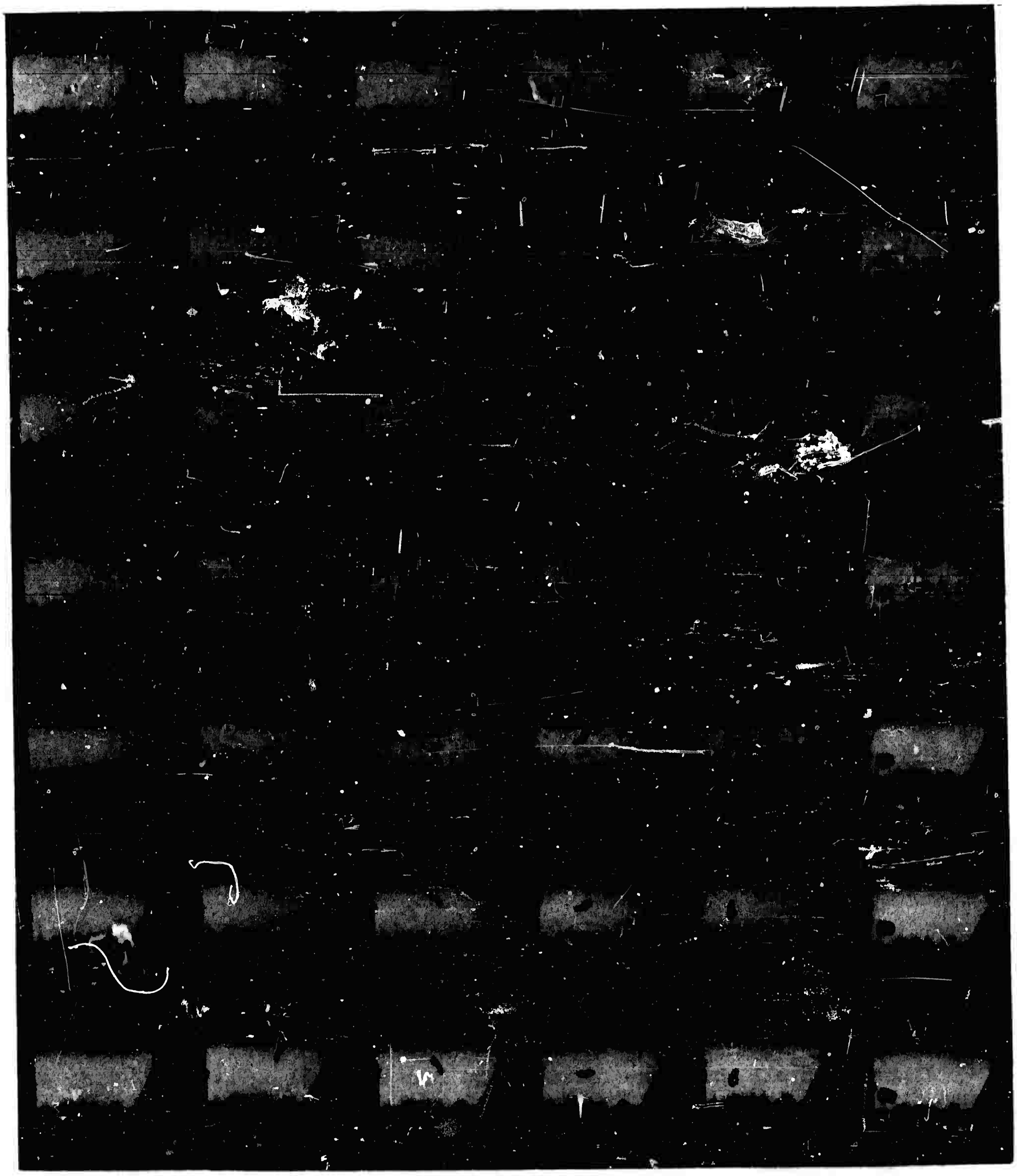


Flight of Spall which was Initiated by Tube Round 83. Plate Obliquity 60°; Round Striking Velocity 2568 fps; Spall Velocity 312 fps; Spall Weight 9.10 lb; Spall Energy 13,800 ft-lb.



Flight of Spall which was Initiated by Tube Round 82. **Plate Obliquity 60°;** Round Striking Velocity 2574 fps; Spall Velocity 371 fps; Spall Weight 8.94 lb; Spall Energy 19,100 ft-lb.

Flight of Spall which was Initiated by Tube Round 71. Plate Obliquity 60°; Round Striking Velocity 2603 fps; Spall Velocity 359 fps; Spall Weight 8.66 lb; Spall Energy 15,200 ft-lb.



B27865: X-Ray Photograph of T_42E3, HEP Shell. Recovered Round, Tube Round 172, Striking Velocity 1000 fps at 60°.